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KEYWORDS: White Oak Lake, fish, waterfowl, vertebrate fauna, phosphorous-32, Strontium-90, gross beta radioactivity, cesium-137, Cobalt-60, ruthenium-106

ABSTRACT: Document consisted of four parts: fish population of White Oak Lake; accumulation of radiomaterials by fishes; survey of waterfowl population and accumulation of radiomaterials by waterfowl; and, accumulation of radiomaterials by other vertebrates (frogs, turtles, snakes, selected terrestrial birds and mammals).

A comprehensive survey was conducted to appraise the composition and abundance of various species of fish present in White Oak Lake. The rate of growth, reproductive success, food supply etc. were also evaluated to help determine the overall "condition" of individual fish species.

In the radiochemical analyses of different tissues in selected organisms, high levels of phosphorous-32 (P-32) were observed in waterfowl (specifically coots). Strontium-90 (Sr-90) was observed in bone tissue of several species. Other radionuclides (Cesium-137, Cobalt-60, Ruthenium-106 etc.) were identified in the fish tissue analysis. However, data ~~was~~ were mostly reported as gross beta radioactivity (in counts per minute per gram fresh weight).

REVIEWER: Jim Knight DATE REVIEWED: 11/19/96

Ecological Survey of WOL by Krumholtz 1954
(one volume of three, plus a summary volume)
ORO-XXXX

Coots (ducks) spent winters on WOL because it was a hunting sanctuary during open season and was apparently far south and warm enough for them. During the winter of 1951-52 coots and other species of ducks were trapped and various tissues were analyzed for radionuclides. A lot of algae was found in their stomach contents. Coots had higher gross beta cpm than any other duck species trapped, except 1 gadwall and 1 wood duck reared near WOL. Radiochemical analysis of muscle, caeca and intestines from 1 coot and 1 gadwall (duck) were conducted. Breast muscle from 2 coots was analyzed. Practically all of the radioactivity was emitted by P-32. P-32 was accumulated during phosphorylation (breast muscle is a big and active muscle). P-32 has a 14 day half-life. 3 or 4 days went by before the assay was done, and no decay correction was made, so P-32 could have been even higher. Each bird had about 11 ounces of edible tissue containing about 2.5 microcuries. It was calculated that a person could eat 2.4-6.7 ounces of edible coot tissue without exceeding the MPC for P-32 (no calcs or MPC values shown in results table). Coots, turtles and muskrats also had Sr-90 in bones. The only mention of the Intermediate Pond is that green-winged teals (ducks) preferred it over WOL.

1954 GD

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UNITED STATES OF AMERICA

ORO-587 (Vol. III)

AN ECOLOGICAL SURVEY OF THE VERTEBRATE FAUNA OF WHITE OAK LAKE AND ENVIRONS

By
Louis A. Krumholz

February 1954

Tennessee Valley Authority
Norris, Tennessee

UNITED STATES ATOMIC ENERGY COMMISSION • DIVISION OF TECHNICAL IN

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ORO-587 (Vol. III)
HEALTH AND SAFETY

AN ECOLOGICAL SURVEY OF THE VERTEBRATE FAUNA OF WHITE OAK LAKE AND ENVIRONS

THE FISH POPULATION OF WHITE OAK LAKE,
ROANE COUNTY, TENNESSEE, 1950-1953

INTRODUCTION

One of the most essential parts of a survey of any body of water is a rather accurate appraisal of the composition and abundance of the various species of fish present. Other features to be noted are the rate of growth and the "condition" of the individual fish as indicated by the relationship between their length and weight. In addition, observations on the success of reproduction, the ability of any species to maintain itself as an integral part of the population, food supply, and so on, frequently give clues to the general well-being of the population as a whole

Several methods for estimating the size of the total fish population of a body of water have been developed during recent years. Most of those are based on the procedures devised by C. G. J. Petersen (1896). The salient features outlined by Petersen are: (1) the release of a number of marked fish into the body of water, (2) the recording of the number of fish caught during the period in question, and (3) noting the number of marked fish present among the total catch. From these data it is possible to estimate the total population "P" from the following formula

$$P = \frac{MC}{R}$$

in which M is the number of marked fish in the body of water, C is the total number of fish caught, and R is the number of marked fish recaptured.

One of the most widely adopted methods for estimating fish populations is that developed by Schnabel (1938) in which

$$P = \frac{(AB)}{(C)}$$

where A is the number of fish examined on any day, B is the summation of the number of marked fish in the lake at the time, and C is the summation of the number of recaptured marked fish. Schnabel used the method of maximum likelihood in averaging a series of estimates while the marking was in progress. Krumholz (1944) pointed out that it could be proved algebraically that the Schnabel formula gives yields that are generally too high. However, when the ratio between the number of marked fish and the total population is small, and hence the numbers of recaptured marked fish is necessarily small compared to the number of marked fish in the lake, the formula is adequate for most estimates.

It has been shown by Ricker (1948) that such estimates are valid only if the following assumptions hold true:

1. That the marked fish suffer the same mortality as the unmarked ones;

2. That the marked fish do not lose their mark;

3. That the marked fish are as vulnerable to fishing as the unmarked ones;

4. That the marked fish become randomly mixed with the entire population;

5. That all of the marked fish are reported when caught; and

6. That there is only a negligible amount of recruitment to the catchable population during the time that the study is being carried on.

Even though White Oak Lake has received waste materials from the Oak Ridge National Laboratory during most of its lifetime, there is little reason to believe that the above-mentioned assumptions would be less likely to hold true for the fish population in that lake than in any other. For that matter, White Oak Lake would appear to lend itself more readily to such a study because there is no exploitation of the fishery and consequently there could be no loss of marked fish through that channel. The only changes in the size and composition of the population were from "natural" causes including the presence of excessive wastes or siltation.

Another method for estimating the size and composition of a fish population is to kill off the entire population and then recover, count, weigh, and measure the fish. Although this method has also been widely used, there is no assurance that the entire population can be recovered.

In an effort to obtain as complete data as possible, six semi-annual netting studies of the population were made beginning in the fall of 1950 and ending in the spring of 1953. Immediately following the completion of the last netting study, the lake was partially drained and treated with rotenone and all of the fish killed and recovered so far as possible.

MATERIALS AND METHODS

The kinds of fish present in White Oak Lake during the period of investigation that were captured in the nets were: the bluegill (*Lepomis m. macrochirus*), the largemouth bass (*Micropterus salmoides*), the black crappie (*Pomoxis nigro-maculatus*), the white crappie (*Pomoxis sparoides*), the carp (*Cyprinus carpio*), the goldfish (*Carrasius auratus*), carp x goldfish hybrids, the yellow bullhead (*Ameiurus natalis*), the northern redhorse (*Moxostoma erythrurum*), and the gizzard shad (*Dorosoma cepedianum*). In addition, one common sucker (*Catostomus commersonni*) was caught in the spring of 1952. The only other fish that was present in the lake during the survey, but which was not large enough to be retained in the nets, was the western mosquitofish (*Gambusia a. affinis*).

Hoopnets were used to catch the fish necessary for making the estimates of the fish population. Each net consisted of cotton webbing stretched over six wood hoops of the following diameters from front to rear: 4-1/2 feet, 4-1/4 feet, 4 feet, 3-3/4 feet, 3-1/2 feet, and 3-1/4 feet, with throats or funnels on the first and third hoops. The first throat was finished with four strings which were attached to the inside of the second throat. The second throat was fingered and finished with two strings which in turn were attached to the tail rope at the rear of the net. The tail of the net was fitted with a drawstring so that fish, having entered the front of the net, could be worked toward the rear of the net and removed by loosing the drawstring. Thus, by pulling the tailrope tight, the throats would also be drawn tight and held up and away from the bottom and sides of the net. The entire net was 116 meshes long; the first 32 meshes being 1½-inch bar measure, and the last 84 being 1-inch bar measure.

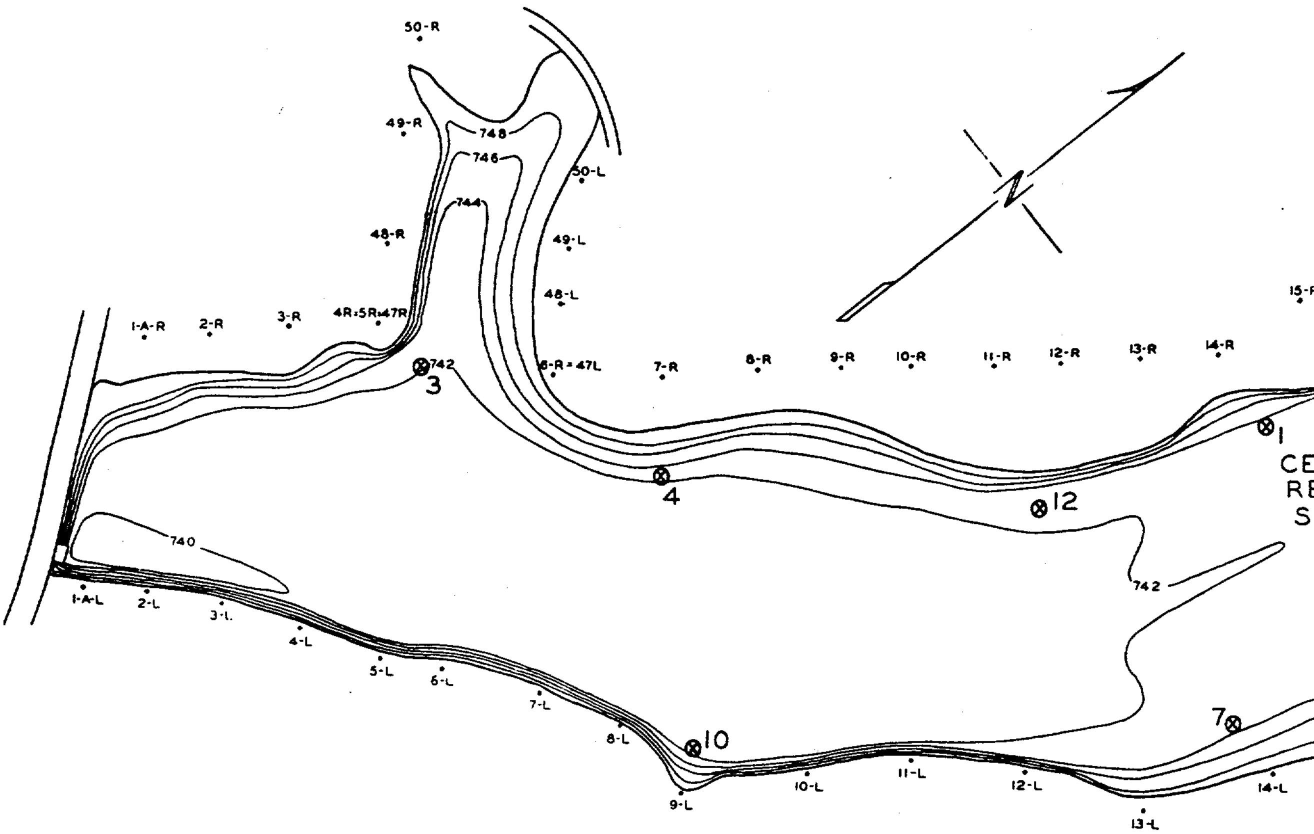
Each net was fitted with a 50-foot lead fastened across the center of the first hoop and a 20-foot wing attached on each side. Both wings and the lead were made of 1½-inch bar webbing and were fitted with floats and weights. Each wing, the lead, and the tail pole were tied to native sassafras poles so that the nets could be firmly placed in the lake.

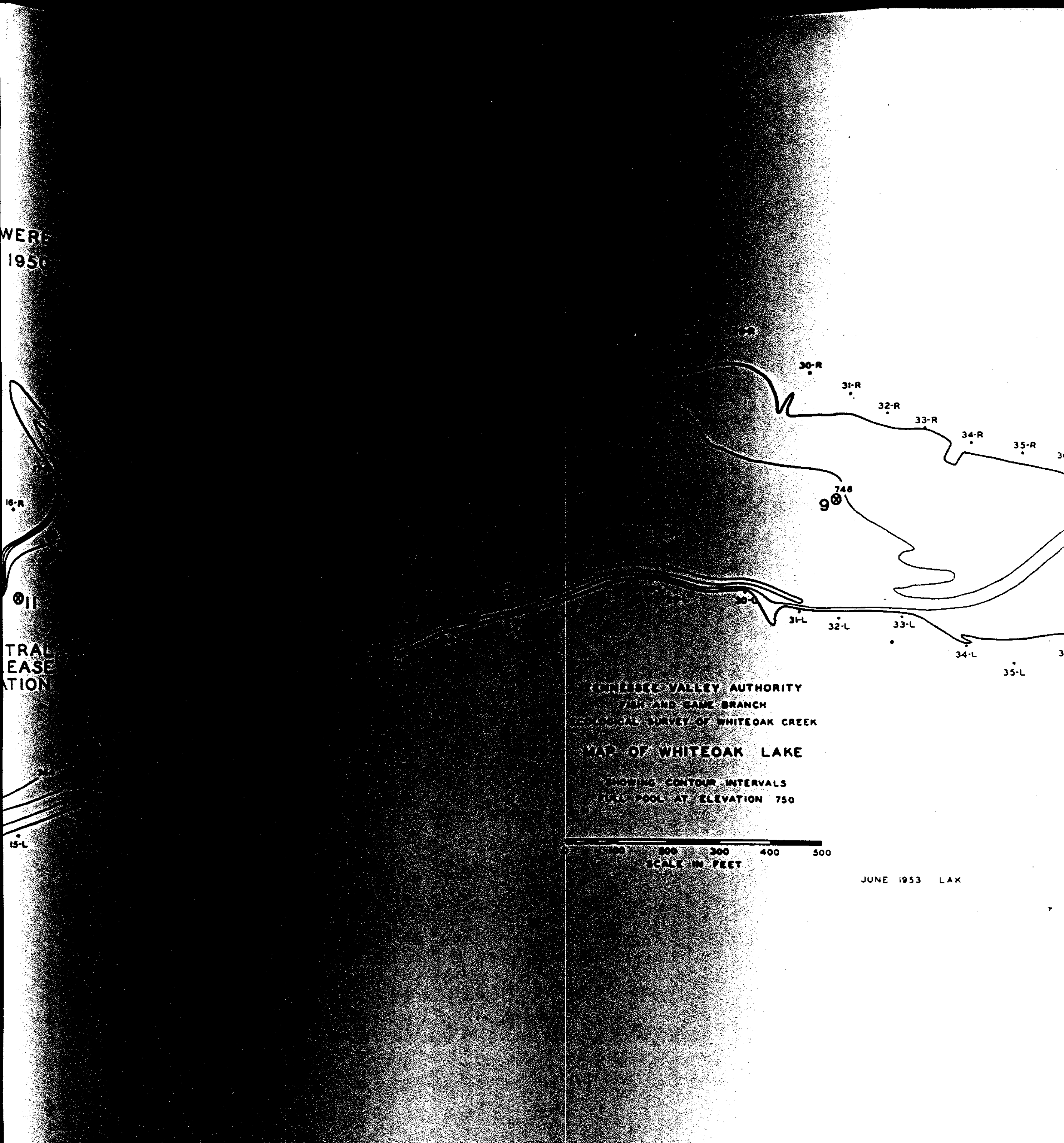
In setting the nets, the lead pole was worked firmly into the lake bottom near the shore. The lead was then stretched out into the lake making an angle of about 45° with the immediated shoreline and the net placed in the desired location. Then the two wing poles were set in place, each making an angle of about 45° with the lead. The hoops were then pulled tight away from the lead and wing poles and the tail pole driven tightly into the bottom. Thus, the net rested on the lake bottom but was held upright by the hoops and poles and accessible to the fish.

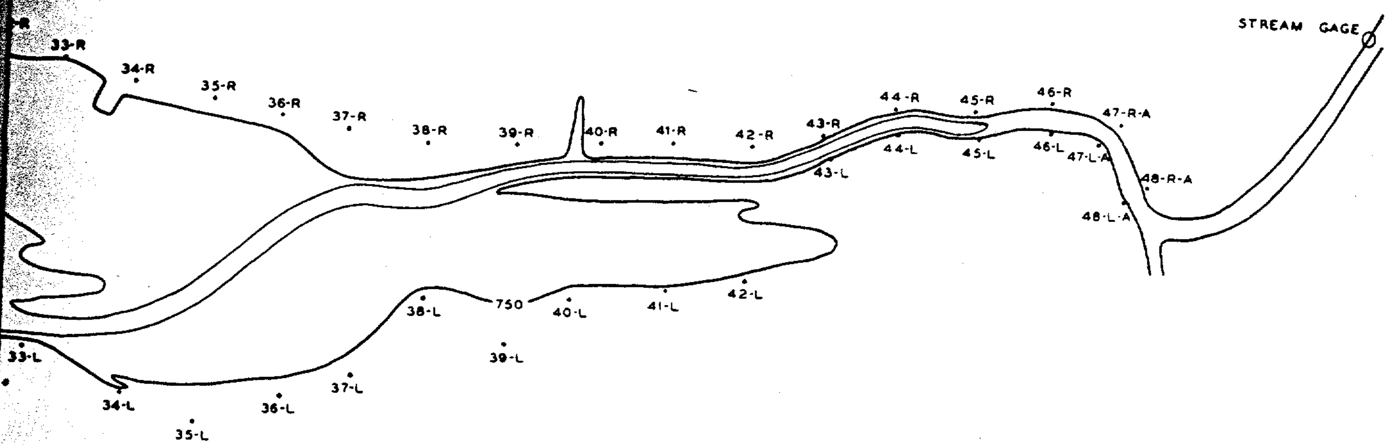
A total of 14 different locations in White Oak Lake were used for setting nets as indicated on the map (Figure 1). Perhaps there were other locations where nets could have been set, but at most other sites the water was either too deep or shallow to accommodate the nets properly, or there was so much brush and debris present that handling the nets would have been impracticable. The nets were generally set with the front facing downstream so that the fish, which usually work upstream near the shore, would enter them. No more than eight nor fewer than five nets were set in the lake at any one time. The nets were set at the various stations as the quality of fishing indicated, and remained at any particular location only so long as the fishing was good.

Each net in the lake was lifted each day and the fish removed and placed in tubs of lake water inside the boat. The net was reset and the fish taken to the central release station (Figure 1). There the fish were sorted to species, measured to fork and total length to the nearest millimeter, marked if necessary, and returned to the lake. In marking the fish, one of the fins was excised at its base so that it would not regenerate. The wounds caused by such marking healed within a week or so leaving a clean scar. Accurate daily records were kept of all fish taken in the nets. If any fish caught in the nets was already marked, the length measurements

FIGURE I. LOCATIONS AT WHICH HOOPNETS
DURING STUDIES OF THE FISH POPULATION




30-R
31-R
32-R
33-R
34-R
35-R
748
9
31-L
32-L
33-L
34-L
35-L
16-R
15-L
TENNESSEE VALLEY AUTHORITY
FISH AND GAME BRANCH
ECOLOGICAL SURVEY OF WHITEOAK CREEK
MAP OF WHITEOAK LAKE
SHOWING CONTOUR INTERVALS
FULL POOL AT ELEVATION 750
100 200 300 400 500
SCALE IN FEET
JUNE 1953 LAK


33-R
34-R
35-R
36-R
37-R
38-R
39-R
40-R
41-R
42-R
43-R
44-R
45-R
46-R
47-R-A
48-R-A
STREAM GAGE
43-L
44-L
45-L
46-L
47-L-A
48-L-A
33-L
34-L
35-L
36-L
37-L
38-L
750
39-L
40-L
41-L
42-L

1953 LAK

were recorded, the mark noted, and the fish returned to the lake. Such marking continued for each species of fish during each of the six estimates until it was believed that an adequate number had been marked--a period of from two to five weeks.

In handling the fish for measurements and marking it was necessary to protect the hands against cuts and abrasions. For such protection it was found that ordinary canvas work gloves were satisfactory.

After the nets had remained in the lake for several days they usually became so dirty that they did not fish efficiently. Accordingly, each net was removed from the lake whenever necessary and cleaned. The cleaning was accomplished by washing the nets with a power spray of hot water. After drying for several hours or overnight, the nets were reset.

Toward the latter part of each of the netting operations, scale samples, length measurements, and weights were taken from representative samples of each species of fish to provide information on the age and growth and the relationship between length and weight. Age and growth determinations were made on the scale-reading machine at the TVA Fish and Game Branch headquarters at Norris, Tennessee.

ESTIMATE OF FISH POPULATION

The most satisfactory way to estimate the total fish population of any body of water is to obtain estimates for the individual species and then combine those estimates into a total. It is usually not satisfactory to treat the different species together as a unit because of the extreme differences in the likelihood of individuals of the different species in entering the nets. For instance, it has been shown by Ricker (1948) in

Indiana that the redear sunfish (Lepomis microlophus) is about ten times as vulnerable to trapping as the very similar bluegill, while its abundance is only about a fifth that of the bluegill. Calculations will show that if the data for the two species are treated as a unit the result would be lower than the combined individual population estimates.

Another factor to be considered is the selectivity of the gear used. The description of the gear used in this study indicated that the smaller individuals of all species could readily pass in and out through the meshes. From this information it has been determined that this study will embrace estimates of only those fishes that had attained the following total lengths in millimeters: bluegill, black crappie, and white crappie - 100; largemouth bass - 200; carp, goldfish, bullheads, and redhorse - 150. Although there is good evidence from previous collections of fish from the lake (Knobf 1950) that the gizzard shad is very abundant, no estimate of the shad population was made because that species was taken infrequently in the nets, and it is so delicate that it cannot withstand the handling necessary for making an estimate.

Using the data at hand, an attempt will be made to estimate only the numbers of fish that were readily caught in the nets. Such an estimate will include the majority of the total weight of the species concerned. There is little need to compare the estimates arrived at by using the different formulae, and the one derived by Schnabel will be used throughout.

The six semi-annual estimates were handled individually and then compared as a group. The detailed derivation of the estimate for each species is given only for those made during the first study, and only the figures of the final estimates made during the last five studies will be used. The details for the six semi-annual netting studies follow:

1. First Fall Estimate - August 31 through October 6, 1950. Nets were set at Stations 1 through 13 for varying periods of time (Krumholz, 1951a). A total of six nets were fished continuously. All fish caught through September 17 were marked by excising the left pectoral (LP) fin.

2. First Spring Estimate - March 21 through April 25, 1951, with the exception of two days, April 13 and 15 (Krumholz, 1951b). Six nets were fished continuously and were located for varying periods of time at Stations 1 through 8, Station 12, and Station 14. All fish caught through April 7 were marked by excising the right pectoral (RP) fin.

3. Second Fall Estimate - September 25 through October 29, 1951 (Krumholz and Miller, 1952). Seven nets were fished continuously during the period and were set at each of the 14 stations some time or another. All fish caught were marked by excising the left pelvic or ventral (LV) fin. The catches of black crappies were so large early in the study that only those caught through October 4 were marked. Conversely, inasmuch as only 11 largemouth bass were taken during the entire study, all of them were marked.

4. Second Spring Estimate - March 17 through April 21, 1952 (Miller and Krumholz, 1952). Seven nets were fished continuously and were rotated among the 14 stations. All fish were marked by excising the right pelvic or ventral (RV) fin. Such marking continued for the black crappie through April 5, for the redhorse through April 9, for the white crappie through April 10, for the bluegill through April 11, for the bullheads and shad through April 12, for the carp through April 15, and for the largemouth bass through the entire period.

5. Third Fall Estimate - September 22 through October 29, 1952 (Miller, 1953a). Seven nets were fished continuously and rotated among the 14 stations. After two weeks of consistently poor fishing an additional net was set on October 6 and was reset in a different location every two days in an effort to find out whether or not the fish were congregating in any one place. After two weeks of such sampling the additional net was removed. All unmarked fish taken during the entire study were marked by excising the left pectoral (LP) fin.

6. Third Spring Estimate - March 16 through April 20, 1953 (Miller, 1953b). Eight nets were used for 23 of the 35 days of the study and only seven nets for the remaining period. The individual nets were rotated for different periods of time between the 14 stations. All fish were marked by excising the dorsal fin or an adequate part of it at its base. The marking continued for black crappies through April 10, and for all other species through April 15.

In all estimates the carp, goldfish, and carp x goldfish hybrids were considered as one species.

First Fall Estimate, September - October, 1950

A total of 3,356 fish were caught during this study. Of those, 1,992 were marked, and 355 of the marked fish were recaptured.

Bluegills. A total of 1,119 bluegills were examined, 508 were marked and 70 of the marked fish were recaptured. The estimate of the population, together with the data on the fish handled, marked, and recaptured, are given in Table 1. Each of the year classes, 1946, 1947, 1948, and 1949, were represented in the catch.

Table 1. Estimate of the size of the bluegill population of White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number marked already in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	31	30						
Sept. 1	17	17	30	510	510			
2	20	20	47	940	1450			
3	28	26	67	1876	3333	1	1	3333
4	30	28	93	2790	6123	1	2	3062
5	27	27	121	3267	9390		2	4695
6	17	16	148	2516	11906	1	3	3969
7	7	7	164	1148	13054		3	4351
8	20	20	171	3420	16474		3	5491
9	23	21	191	4393	20867	1	4	5217
10	44	43	212	9328	30195	1	5	6039
11	42	42	255	10710	40905		5	8181
12	45	41	297	13365	54270	4	9	6030
13	26	26	338	8788	63058		9	7006
14	21	19	364	7644	70702	2	11	6427
15	20	18	383	7669	78362	2	13	6028
16	12	12	401	4812	83174		13	6398
17	99	95	413	40887	124061	4	17	7298
18	93		508	47244	171305	7	24	7138
19	92		508	46736	218041	7	31	7034
20	65		508	33020	251061	8	39	6437
21	52		508	26416	277477	5	44	6306
22	33		508	16764	294241	3	47	6260
23	28		508	14224	308465	1	48	6426
24	39		508	19812	328277	5	53	6194
25	37		508	18796	347073	3	56	6198
26	23		508	11684	358757		56	6406
27	16		508	8128	366885	1	57	6437
28	19		508	9652	376537		57	6606
29	5		508	2540	379077		57	6650
30	12		508	6096	385173	2	59	6528
Oct. 1	30		508	15240	400413	3	62	6458
2	6		508	3048	403461	1	63	6404
3	13		508	6604	410065	3	66	6213
4	9		508	4572	414637	2	68	6098
5	13		508	6604	421241	2	70	6018
6	5		508	2540	423781		70	6054

Black crappies. During the netting operations, 760 individuals were caught, of which 386 were marked and 73 of the marked fish recaptured. The data for the numbers of fish examined, marked, and recaptured, together with the estimate of the population are listed in Table 2. From these data it is evident that the black crappie is about twice as vulnerable to hoop-netting as the bluegill. Even though there were 508 marked bluegills in the lake as compared with 386 marked black crappies, there were only 70 bluegills recaptured whereas 73 black crappies returned to the nets. The final estimate of the number of black crappies was a little less than half the number of bluegills. Still, the black crappies, both marked and unmarked, although fewer in number than the bluegills, were taken with relatively greater frequency than the bluegills. Among the black crappies the 1946, 1948, and 1949 year classes were represented.

White crappies. Although a total of 98 white crappies were caught, only 3 of the 51 fish marked during the study were recaptured. Such a small number of recaptures can hardly be expected to give as reliable an estimate as a larger one. However, the estimate of 1,200 white crappies may be a fair indication of their abundance. They were not as abundant as the black crappies in September 1950, although three year classes, 1947, 1948, and 1949 were represented. The data on the numbers of fish handled, marked, and recaptured, along with the estimated size of the population are listed in Table 3.

Largemouth bass. Largemouth bass are notoriously difficult to catch in hoopnets. Even in populations where bass are known to be plentiful (Bennett, 1948), the take in hoopnets is limited. In the present study, 49 of the 71 bass caught in the nets were marked, and 16 of the marked fish

Table 2. Estimate of the size of the black crappie population of White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number marked already in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	28	28						
Sept. 1	12	12	28	336	336			
2	6	6	40	240	576			
3	15	14	46	690	1266	1	1	1266
4	17	16	60	272	1538	1	2	769
5	25	25	76	1900	3438		2	1719
6	35	34	101	3535	6973		2	3487
7	23	23	135	3105	10078		2	5039
8	23	21	158	3634	13712	2	4	3428
9	31	30	179	5549	19261	1	5	3852
10	52	49	209	10868	30129	3	8	3766
11	35	35	258	9030	39159		8	4895
12	41	40	293	12013	51172	1	9	5686
13	22	20	333	7326	58498	2	11	5318
14	8	7	353	2024	60522	1	12	5044
15	6	4	360	2160	62682	2	14	4477
16	5	4	364	1820	64502	1	15	4300
17	20	18	368	7360	71862	2	17	4227
18	28		386	10108	82670	6	23	3594
19	20		386	7360	90030	4	27	3334
20	61		386	23546	113576	10	37	3070
21	17		386	6562	120138	2	39	3080
22	10		386	3860	123998	3	42	2952
23	20		386	7360	131358	2	44	2985
24	36		386	13896	145254	5	49	2964
25	46		386	17756	163010	7	56	2911
26	27		386	10422	173432	5	61	2843
27	5		386	1930	175362		61	2875
28	12		386	4632	179994	2	63	2857
29	7		386	2702	182696	2	65	2811
30	13		386	5018	187714	2	67	2802
Oct. 1	10		386	3860	191574	1	68	2817
2	5		386	1930	193504	1	69	2804
3	8		386	3088	196592		69	2849
4	3		386	1158	197750		69	2866
5	16		386	6176	203926	2	71	2872
6	12		386	4632	208558	2	73	2857

Table 3. Estimate of the size of the white crappie population of White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number already marked in lake	Product	(AB) Sum of product	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	3	3						
Sept. 1	2	2	3	6	6			
2	2	1*	5	10	16	1	1	16
3	1	1	5	5	21		1	21
4	4	4	6	24	45		1	45
5	5	5	10	50	95		1	95
6	5	5	15	75	170		1	170
7	2	2	20	40	210		1	210
8	6	6	22	132	342		1	342
9	2	2	28	56	398		1	398
10	7	7	30	210	608		1	608
11	6	6	36	216	824		1	824
12	7	7	43	301	1125		1	1125
13	4	4	47	148	1273		1	1273
14	1	1	48	48	1321		1	1321
15	1	1	49	49	1370		1	1370
16					1370		1	1370
17	2	2	51	102	1472		1	1472
18	2		51	102	1574	1	2	787
19	3		51	153	1727		2	864
20	5		51	255	1982		2	991
21	2		51	102	2084		2	1042
22	1		51	51	2135		2	1068
23	1		51	51	2186		2	1093
24	4		51	204	2390		2	1198
25	6		51	306	2696		2	1348
26	1		51	51	2747		2	1374
27	1		51	51	2798		2	1399
28			51		2798		2	1399
29	1		51	51	2849		2	1425
30			51		2849		2	1425
Oct. 1	1		51	51	2900		2	1500
2	7		51	357	3257		2	1629
3	2		51	102	3359		2	1679
4	1		51	51	3410	1	3	1137
5			51		3410		3	1137
6			51		3410		3	1137

*On September 2 the marked fish recaptured in the net was accidentally killed. Accordingly it was removed from the number of fish already marked in the lake.

were recaptured. Because of its predatory habits, the largemouth bass is seldom an abundant fish in any population. However, the estimate of 130-140 fish (about 4 fish per acre) for this study is lower than expected for this region. Members of the 1945, 1946, 1947, 1948, and 1949 year classes were represented in the catch. The estimate of the population, the numbers of fish handled, marked, and recaptured, are listed in Table 4.

Early in March 1950, 200 adult largemouth bass were jaw-tagged and released in White Oak Lake by personnel of the Fish and Game Branch of the TVA, who thereby hoped to replenish the population. During the fall netting operations, only two tagged individuals were caught and one of those was taken a second time. From this preliminary information it is apparent that the 1950 planting was not successful. It may be, however, that the fish spawned and their offspring will appreciably increase the numbers of bass in the lake.

Carp. The most abundant fish from the standpoint of total weight in the fish population of White Oak Lake, as shown by this study, is the carp. It is usually not difficult to trap carp and the accompanying estimate is believed to be fairly accurate. A total of 829 carp were caught in the nets, 718 were marked, and 46 were recaptured. The data on which the estimate was based are listed in Table 5. Individuals of the 1946, 1947, 1948, and 1949 year classes were represented in the catch. More carp were marked during this study than any other species. For some unknown reason the catch of carp was relatively high during the first ten days of the study and then fell off markedly. The reason for the decline is not obvious.

Carp have frequently been accused of crowding out more desirable food species from lakes in various parts of the country. The evidence in

Table 4. Estimate of the size of the largemouth bass population of White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number already marked in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	4	4						
Sept. 1	2	2	4	8	8			
2	2	2	6	12	20			
3	6	6	8	48	68			
4	7	7	14	98	166			
5	4	4	21	84	250			
6	10	10	25	250	500			
7	5	3	35	175	675	2	2	338
8	2	2	38	76	751		2	376
9	4	2	40	160	911	2	4	228
10	2	1	42	84	995	1	5	199
11	5	2	43	215	1210	3	8	151
12			45		1210		8	151
13	3	2	45	135	1345	1	9	149
14	3	1	47	141	1486	2	11	135
15	1	1	48	48	1534		11	139
16			49		1534		11	139
17			49		1534		11	139
18	1		49	49	1583	1	12	132
19			49		1583		12	132
20			49		1583		12	132
21	1		49	49	1632		12	136
22			49		1632		12	136
23			49		1632		12	136
24	3		49	147	1779	1	13	137
25			49		1779		13	137
26	1		49	49	1828		13	141
27	1		49	49	1877	1	14	134
28			49		1877		14	134
29			49		1877		14	134
30			49		1877		14	134
Oct. 1	1		49	49	1926	1	15	128
2	2		49	98	2024		15	135
3			49		2024		15	135
4			49		2024		15	135
5			49		2024		15	135
6	1		49	49	2073	1	16	130

Table 5. Estimate of the size of the carp population of White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number marked already in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	173	173						
Sept. 1	128	126	173	22144	22144	1	1	22144
2	125	119	299	37375	59519	6	7	8503
3	68	68	418	28424	87943		7	12563
4	48	47	486	23328	111271	1	8	13909
5	19	17	533	10127	121398	2	10	12140
6	32	31	550	17600	138998	1	11	12636
7	26	25	581	15106	154104	1	12	12842
8	52	49	606	31512	185616	3	15	12374
9	19	19	655	12445	198061		15	13204
10	11	10	674	7381	205442	1	16	12840
11	12	12	684	8208	213650		16	13353
12	6	5	696	4176	217826	1	17	12813
13	4	4	701	2804	220630		17	12978
14	3	2	705	2115	222745	1	18	12735
15	6	4	707	4242	226987	2	20	11349
16	5	3	711	3555	230542	2	22	10479
17	5	5	714	3570	234112		22	10641
18	3		719	2157	236269	1	23	10273
19	8		719	5752	242021	2	25	9681
20	4		719	2876	244897		25	9796
21	9		719	6471	251368	1	26	9668
22	9		719	6471	257839	3	29	8891
23	7		719	5033	262872	3	32	8215
24	11		719	7909	270781	6	38	7126
25	7		718*	5026	275807		38	7258
26	12		718	8618	284423	3	41	6937
27	3		718	2154	286577	3	44	6513
28	5		718	3590	290167	1	45	6448
29	1		718	718	290885		45	6464
30	2		718	1436	292321		45	6496
Oct. 1	1		718	718	293039		45	6512
2	1		718	718	293757		45	6528
3	2		718	1436	295193	1	46	6417
4	1		718	718	295911		46	6433
5			718		295911		46	6433
6	2		718	1436	297347		46	6464

*On the previous day one of the marked fish caught in the net was dead. Accordingly it was removed from the number of marked fish in the lake.

support of this argument is apparently sound and is largely based on the ecology of the carp. Belonging to the minnow family, the carp feeds on any nourishing material that is found along the lake bottom. In feeding, the water is roiled to a considerable extent and the fishes that feed by sight, notably the bass, crappies, and bluegills, are automatically placed under a handicap. Such a roiling of the water has been shown to cause a deposit of as much as eight inches of silt over areas of the lake bottom protected from carp (Threinen and Helm, 1954). Furthermore, the carp attacks the beginning of the food chain thus competing directly with the other fish, but only under conditions to his liking. The carp has also frequently been accused of uprooting aquatic vegetation and it may be that the presence of large numbers of carp is one of the primary causes for the virtual absence of rooted aquatic plants in White Oak Lake.

The carp grows very rapidly, often reaching lengths of 10 inches or more during the first summer of life, and thus does not provide forage for the piscivorous species for a very long time. The carp broadcasts its eggs and spawns over a wide area, and, although it provides no care for its eggs or young, the extremely large numbers of eggs deposited virtually assures the success of the brood. The tremendous amount of activity that accompanies the spawning act for carp makes spawning for other species in the area a rather precarious undertaking.

Bullheads. Bullheads are relatively easy to trap and frequently return to the same net time after time. A total of 306 bullheads were caught during the study, 167 were marked, and 116 of the marked fish recaptured. One of the marked fish was recaptured in four different nets for a total of six times. The estimate of the size of the bullhead population, together with the data on the number of fish caught, marked, and recaptured are listed in Table 6.

Redhorse. The estimate of the size of the redhorse population was based on the information supplied by the recapture of 31 of 113 fish that had been marked during the study. A total of 173 redhorse were examined (Table 7). The 1948 year class was the only one represented.

Total fishes. In estimating the total fish population by combining the data from all species and treating them as a unit, the figure arrived at is 13,050 individuals. However, as mentioned earlier, such a procedure is invalid and tends to give an estimate that is considerably lower than the additive total obtained by treating the species singly and then combining the totals. By adding the totals as follows, bluegills - 6,100, black crappies - 2,850, white crappies - 1,200, largemouth bass - 135, carp - 6,450, bullheads - 250, and redhorse - 375, the more accurate estimate of the size and composition of the fish population is found to be 17,360. This latter estimate is approximately one-third (31.9 percent) higher than the former.

First Spring Estimate, March - April, 1951

During this study, a total of 4,073 fish were caught in the nets. Of those, 1,884 were marked and 623 of the marked fish were recaptured.

Bluegills. During the course of the study there were 1,611 bluegills caught. Of those fish, 625 were marked and 140 of the marked fish were recaptured. From these data it was estimated that there were about 5,600 bluegills of a length greater than four inches in the lake at that time. As in the catch during the study of the previous fall, each of the

Table 6. Estimate of the size of the bullhead population in White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number marked already in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	37	37						
Sept. 1	53	43	37	1961	1961	10	10	196
2	22	9	80	1760	3721	13	23	162
3	9	5	89	801	4522	4	27	167
4	15	9	94	1410	5932	6	33	180
5	42	20	103	4326	10258	22	55	187
6	16	6	123	1968	12226	10	65	188
7	13	8	129	1677	13903	5	70	199
8	17	9	137	2329	16232	8	78	208
9	9	6	146	1314	17546	3	81	217
10	5	1	152	760	18306	4	85	215
11	4	4	153	612	18918		85	223
12	1	1	157	157	19075		85	225
13	3	2	158	474	19549	1	86	227
14	6	4	160	960	20509	2	88	233
15			164		20509		88	233
16	5	1	146	820	21329	4	92	232
17	10	2	165	1650	22979	8	100	230
18	7		167	1169	24148	5	105	230
19	5		167	835	24983	3	108	231
20	3		167	501	25484	1	109	234
21			167		25484		109	234
22	2		167	334	25818	1	110	235
23			167		25818		110	235
24	3		167	501	26319	2	112	235
25	8		167	1336	27655	2	114	243
26	2		167	334	27989		114	246
27			167		27989		114	246
28	1		167	167	28156		114	247
29			167		28156		114	247
30			167		28156		114	247
Oct. 1	5		167	835	28991	1	115	252
2			167		28991		115	252
3			167		28991		115	252
4	2		167	334	29325	1	116	253
5			167		29325		116	253
6	1		167	167	29492		116	254

Table 7. Estimate of the size of the population of redhorse in White Oak Lake, Roane County, Tennessee, September 1950

Date 1950	(A) Number of fish examined	Number of fish marked	(B) Number marked already in lake	Product	(AB) Sum of products	Number of returns	(C) Sum of returns	Estimate of population
Aug. 31	15	15						
Sept. 1	10	10	15	150	150			
2	9	9	25	225	375			
3	14	12	34	476	851	2	2	426
4	6	6	46	276	1127		2	564
5	8	6	52	416	1543	2	4	386
6	12	10	58	696	2239	2	6	373
7	9	9	68	612	2851		6	475
8	11	10	77	847	3698	1	7	528
9	7	7	87	609	4307		7	615
10	4		94	376	4683	4	11	426
11	7	5	94	658	5341	2	13	411
12	9	6	99	891	6232	2	15	415
13	5	3	105	525	6757	2	17	397
14	1	1	108	108	6865		17	404
15	1	1	109	109	6974		17	410
16	2	2	110	220	7194		17	423
17	1	1	112	112	7306		17	430
18	3		113	339	7645	1	18	425
19	1		113	113	7758		18	431
20	3		113	339	8097	1	19	426
21	4		113	452	8549	2	21	407
22	3		113	339	8888	2	23	386
23	3		113	339	9227	1	24	384
24	2		113	226	9453		24	394
25	3		113	339	9792	2	26	377
26	4		113	452	10244	3	29	353
27	3		113	339	10583	1	30	353
28	2		113	226	10809		30	360
29	1		113	113	10922		30	364
30			113		10922		30	364
Oct. 1	2		113	226	11148		30	372
2	2		113	226	11374	1	31	367
3	3		113	339	11713		31	378
4			113		11713		31	378
5			113		11713		31	378
6			113		11713		31	378

year classes 1946, 1947, 1948, and 1949 were represented.

The estimate of 5,600 bluegills in the spring of 1951 indicates that there was a loss in numbers of about 8 percent from the 6,100 fish estimated to have been present the previous fall.

Black crappies. A total of 1,462 black crappies were caught during the study. Approximately half of those individuals (742 fish) were marked and 342 of the marked fish were recaptured. Here, again, it is indicated that the black crappie is about twice as vulnerable to hoopnetting as the bluegill. Of the 625 marked bluegills in the lake, only 140 (22.4 percent) were recaptured, whereas of the 742 marked black crappies, there were 342 (46.1 percent) recaptured.

From the data at hand it was estimated that there were about 2,200 black crappies, more than 4 inches long, in the population in the spring of 1951. That estimate indicates that there was a loss in numbers of 22.8 percent from the estimated 2,850 black crappies of the fall of 1950.

An examination of the length frequency distributions of the catches for the two studies indicates that the over-winter loss was traceable primarily to the virtual absence of the 1946 year class in the spring catch. The disappearance of that year class was partially compensated for by the increased numbers of the 1950 year class taken during the spring. Only four individuals of the 1950 year class were caught in the fall, whereas 172 were taken in the spring. Those fish had obviously grown enough during the winter months to be retained in the nets.

White crappies. There were 345 white crappies caught during the spring of 1951. Of those 345 fish, 129 were marked and 100 of the marked fish were recaptured. From these data it was estimated that the spring population of white crappies in 1951 consisted of only about 340 individuals.

A comparison of the estimates from the spring with the preceding fall indicates that there was a decline of about 70 percent in the numbers of fish over winter. Here, again, it should be brought to mind that the two estimates for white crappies may not be reliable because of the meagre data. In the fall there were only 98 white crappies caught as compared to 345 taken in the spring. Furthermore, there were only three recaptures from 51 marked fish in the fall while in the spring 100 of the 129 marked fish were recaptured. In the spring of 1951, the ratio of black crappies to white crappies in the combined catches of the two species was 4.2 to 1 whereas that ratio the preceding fall was 7.8 to 1. It may be that the white crappie is less vulnerable to hoopnetting in the fall than in the spring, or it may be that the habits of the two species differ considerably from one season to another.

Largemouth bass. Only five largemouth bass were taken in the nets during the spring study. All of those fish were marked and one was recaptured. No estimate could be made from these data. All of the bass caught were large, weighing at least two pounds each, and none of the smaller individuals caught the preceding fall were caught nor were any of the tagged fish.

Carp. As in the estimate of the carp population for the fall of 1950, the carp was the most abundant fish in the lake from the standpoint of total weight. Although the spring estimate indicated that there were fewer carp than bluegills, the individual carp weighed considerably more.

Only slightly more than half as many carp were caught in the spring of 1951 as in the fall of 1950. The reason for such a drop in catch is not obvious. However, the percentage of marked fish recaptured during the spring (6.6 percent) was almost identical with that of the fall (6.4 percent), and the spring estimate of about 4,830 individuals is believed to be as reliable as the one made in the fall. There were 482 carp taken in the nets in the spring of 1951. Of those, 289 were marked and there were 19 recaptures.

The average size of the carp in the spring catch was smaller than that in the fall. The spring catch consisted primarily of individuals of the 1948 and 1949 year classes whereas the fall catch was comprised, in a large part, by members of the 1946 and 1947 year classes as well. The difference in the two estimates indicates that there was a loss of about 25 percent in the number of carp in the population over winter.

Bullheads. During this study, 103 bullheads were caught. Of those, 63 were marked and 11 marked fish were recaptured. The estimated population of about 390 bullheads for the spring of 1951 is half again as large as the fall estimate. The most apparent reason for such an increase was the greater relative abundance of small bullheads in the spring catch. Fish of a lesser length than eight inches made up only about 16 percent of the fall catch whereas in the spring they made up about 35 percent.

Redhorse. A total of only 65 redhorse were caught in this study. Of those fish, 31 were marked and 10 of the marked ones were recaptured. The estimate of about 145 fish based on these data is not reliable. However, when compared with the estimate of the previous fall there is an indication of a loss of about 62 percent of the population.

Total fishes. Addition of the individual estimates of bluegills - 5,600, black crappies - 2,200, white crappies - 340, carp - 4,830, bullheads - 390, and redhorse - 145, gives a total of 13,505 fish in the population exclusive of the largemouth bass. A comparison of the two estimates of the total fish population shows that there was a loss of about 3,720 fish during the winter, representing a decrease of 22 percent.

During the winter of 1950-51, there was a heavy mortality of gizzard shad in White Oak Lake. The fish were of much the same size, from 13 to 15 inches long, and it is believed that the mortality was a natural one. It was estimated that several thousand shad died during the winter, and, inasmuch as the fish were of the same size, and primarily of the same age, it is believed that that particular year class has now virtually disappeared.

Second Fall Estimate, September - October, 1951

A total of 5,767 fish were caught during this study. Of those, 2,409 were marked and 643 of the marked fish were recaptured.

Bluegills. During the five-week period there were 1,902 bluegills caught, of which 615 were marked and 41 marked fish recaptured. From these data it was estimated that there were about 22,000 bluegills of a greater length than four inches in the lake at the time. This estimate represents almost a four-fold increase in the numbers estimated for the previous spring, and nearly as great an increase over that of the preceding fall. The bluegill population consisted primarily of members of the 1948, 1949, and 1950 year classes and the 1946 and 1947 year classes were scarce.

Black crappies. A total of 2,857 black crappies were taken in the nets during this study. Of those, 1,140 were marked and 467 of the marked fish were recaptured. From these data it was estimated that there were about 5,100 black crappies present that were more than four inches long. That estimate represents a greater than two-fold increase over the spring estimate, and nearly a doubling of the estimated size of the population for the fall of 1950. Representatives of four year classes, 1948, 1949, 1950, and 1951 were present in the catch.

White crappies. There were 154 white crappies taken in the nets during the autumn of 1951. Of those, 64 were marked and 16 of the marked fish were recaptured. An estimate based on these data indicates that there were about 450 white crappies in White Oak Lake in October 1951; an increase of about 17 percent over the estimate of 375 individuals for the preceding spring. In contrast to both the black crappies and bluegills, where there were increases in the populations from October 1950 to October 1951, there was a decrease of more than 60 percent from the estimated population of 1,140 white crappies in October 1950.

Largemouth bass. During this study there were only 11 largemouth bass taken in the nets. All of those fish were marked and none of them was recaptured. No estimate of the size of the bass population was made. None of the fish taken in this study were tagged fish that had been released in March 1950. Most of the bass taken in the nets were thin and emaciated. It may be that the extreme turbidity of the lake water made it virtually impossible for the bass to obtain enough food to maintain a healthy population.

Carp. A total of 264 carp were taken during this fall netting period, 203 were marked, and 12 of the marked fish were recaptured. Again, as in the spring catch of 1951, there were only slightly more than half as many carp caught as in the immediately preceding study. However, the percentage of marked fish that were recaptured has remained fairly constant for all three periods.

The estimate of the number of carp in White Oak Lake in October 1951 was about 2,250 individuals. That estimate represents a drop of about 47 percent from the 4,825 carp estimated to have been present the previous spring, which in turn represented a decrease of about 25 percent from the estimated 6,450 individuals present in October 1950.

Bullheads. There were 347 bullheads taken in the nets during the present study. Of those fish, 255 were marked and 54 of the marked fish were recaptured. The size of the bullhead population was estimated to be about 875 fish. That estimate represents a more than two-fold increase over the estimated 390 individuals of the preceding spring study, and a three-and-one-half-fold increase over the estimate of the preceding fall.

Redhorse. During this study there were 133 redhorse caught in the nets, of which 64 were marked, and 51 marked fish recaptured. It was estimated that there were about 115 individuals present in the redhorse population; an indication that there has been a rather steady decline in the size of the population since the first estimate was made in October 1950.

A total of 99 gizzard shad were taken in the nets. Of those, 57 were marked and returned to the lake and 2 of the marked fish were recaptured. No estimate of the size of the shad population was made.

Total fishes. The estimate of the total size of the fish population arrived at by adding the individual estimates follows: bluegills - 22,000; black crappies - 5,100; white crappies - 450; largemouth bass - no estimate; carp - 2,550; bullheads - 875; redhorse - 115; total population - 31,090 fishes large enough to be retained by the nets.

Second Spring Estimate, March - April, 1952

During this study, a total of 5,635 fish were caught in the nets. Of those 2,953 were marked and released, and 1,566 marked fish were recaptured.

Bluegills. During the five-week period, 1,697 bluegills were taken in the nets, 1,050 were marked, and 176 marked fish were recaptured. From these data it was estimated that there were about 6,500 bluegills present at the time the estimate was made. This estimate represents a decrease to less than one-third of the 22,000 bluegills estimated to have been present in October 1951. However, it represents an increase over the 5,600 individuals estimated to have been there in May 1951.

Black crappies. A total of 3,353 black crappies were caught, 1,466 were marked, and 1,307 marked fish were recaptured. Here, as in the three previous studies, it is apparent that black crappies are considerably more vulnerable to hoopnetting than are the bluegills. It was estimated that there were about 2,700 black crappies present in the lake at the time of this study. This estimate represents a drop in the size of the population to about half of that for the preceding fall. However, it indicates an increase of about 25 percent over the 2,200 black crappies estimated to have been present in May 1951.

White crappies. There were only 65 white crappies caught during the study. Of those, 35 were marked and 29 of the marked fish recaptured. An analysis of these data indicated that there were only about 50 white crappies in the lake in May 1952, a decided decrease from any preceding estimate.

Largemouth bass. During the study only 15 largemouth bass were caught, all were marked, and 3 of the marked fish were recaptured. No estimate of the size of the bass population was made. The bass taken this spring were in better condition than those caught the preceding October. Perhaps that change in condition was due to the relative clearness of the water of the lake during the half year immediately preceding the study which allowed the bass a better opportunity for feeding.

Carp. A total of 167 carp were caught, 146 were marked, but only 4 of the marked fish were recaptured. Similarly as in the autumn of 1951, there were only slightly more than half as many carp caught as during the study immediately preceding. However, the percentage of marked fish recaptured fell off markedly. From these rather meagre data, it was estimated that there were about 3,100 carp present during the study. That figure represents an increase of about 20 percent over the estimated 2,550 for the autumn of 1951, but also represents a decrease of more than 25 percent from the 4,825 individuals estimated to have been present in May 1951.

Bullheads. There were 98 bullheads caught, 70 were marked, and 12 of the marked fish were recaptured. The size of the bullhead population was estimated to be about 350 fish, a decrease to less than half the number figured to have been present in October 1951. However, it represents only a slight decrease from the 390 individuals present in May 1951.

Redhorse. During this study there were 73 redhorse taken in the nets. Of those, 43 were marked and 29 of the marked fish were recaptured. It was estimated that there were about 75 redhorse in the lake in May 1952.

A total of 167 shad, of which 128 were marked and released, and 6 of the marked fish recaptured, were handled during the study. No estimate of the size of the population was made.

Total fishes. The estimate of the total fish population obtained by adding the individual estimates follows: bluegills - 6,500; black crappies - 2,700; white crappies - 50; largemouth bass - no estimate; carp - 3,100; bullheads - 350; redhorse - 75; total fish population - 12,275 individuals.

Third Fall Estimate, September - October, 1952

During this study a total of only 1,611 fish were taken in the nets. Of those, 1453 were marked and released and 115 of the marked fish were recaptured. The total catch was about 72 percent lower than that for the spring of 1952. There is no apparent reason for the catch being so low. The catches during the four preceding studies were usually large enough to serve as bases for estimating the size of the populations. No catastrophes to the fish population as a whole or to any segment of it were noticed at any time and it was assumed that the fish were present. For some reason, however, they avoided the nets. It may be that the protracted period of intense heat and drought affected the movements of the fish. Also, it may be that the lake became overpopulated with stunted fish too small to be held by the nets. Even so, it is expected that many of the larger fish present the previous spring would still be available.

Bluegills. During the 37-day netting period, only 336 bluegills were taken in the nets. Of those, 322 were marked and returned to the lake but no marked fish were recaptured. Thus, no estimate could be made.

Black crappies. A total of 935 black crappies were caught, 841 were marked and released, and 77 of the marked fish were recaptured. It was estimated that 5,075 black crappies large enough to be held in the nets were present. That estimate represents approximately a 50 percent increase over the immediately preceding spring estimate, and was almost identical with the estimate for the autumn of 1951.

White crappies. There were only three white crappies caught during this study and no estimate of the size of the population was made. The small catch corroborates the belief that this species was gradually disappearing from the lake. However, the small take was in line with the decreased catches for other species.

Largemouth bass. Only six largemouth bass were caught during this study. This number, too, corresponds with the overall decrease in catch. However, sufficient numbers of bass on which to base an estimate have not been taken during any study since the first one.

Carp. Inasmuch as only 31 carp were caught and marked, and no marked fish were recaptured, no estimate of the population was made.

Bullheads. There were 155 bullheads taken in the nets during this study, 134 were marked, and 21 marked bullheads were recaptured. The size of the bullhead population was estimated to be 490 fish, an increase of about 40 percent over the immediately preceding estimate, and a decrease of 44 percent from the estimate for the autumn of 1951.

Redhorse. Of the 54 redhorse caught, 36 were marked, and 16 marked fish were recaptured. It was estimated that there were about 55 redhorse present at the time. This lends credence to the previous assumption that this species was gradually and steadily disappearing from the lake.

A total of 93 gizzard shad, of which 80 were marked and one marked fish recaptured, were handled during the study. No estimate of the size of the population was made.

Total fishes. The lack of information on two species of fish of primary importance to the overall population, bluegills and carp, precludes an estimate of the size and composition of the total fish population.

Third Spring Estimate, March - April 1953

A total of 2,777 fish were caught in the nets during this study. Of those fish, 1,834 were marked and returned to the lake and 524 of the marked fish were recaptured. Although that total is considerably greater than that for the fall study in 1952, it was not as large as any of the first four studies in the series.

Bluegills. During this study only 707 bluegills were taken in the nets. Of those, 622 were marked and 48 of the marked fish were recaptured. From these data it was estimated that there were about 4,750 bluegills in the population. That estimate represents a decrease of about 25 percent from the 6,500 individuals of the preceding spring.

Black crappies. A total of 1,409 black crappies were caught, 833 were marked, and 411 of the marked fish were recaptured. It was estimated that there were about 1,800 black crappies in the population large enough to be held by the nets; a greater decrease from the estimated 5,075 fish present the previous fall than could reasonably be attributed to normal over-winter loss.

White crappies. Only 15 white crappies were caught, 6 were marked, and 9 marked fish were recaptured. From these data it was estimated that the entire population of white crappies consisted of the 6 fish caught and marked. This estimate further corroborates the previous statement that this species is disappearing from the lake.

Largemouth bass. Only 4 individuals were caught and marked and none was recaptured. No estimate of the size of the bass population was made.

Carp. A total of 289 carp were taken in the nets during this study, of which 146 were marked and 15 marked fish recaptured. It was estimated that there were about 1,700 carp present in the lake. However, that estimate is believed to be inaccurate. During the netting operations, an infection of near epidemic proportions was present in the carp population. The infection caused the formation of large ulcerous lesions that involved the scales, skin, flesh, and, in some instances, the viscera. During the study, more than one-fourth of the carp taken in the nets were dead and most of the fish handled were infected. If the sampling of the population were representative, the epidemic would have decimated a large part of the population.

Bullheads. During the study 62 bullheads were caught, 47 were marked, and 10 of the marked fish recaptured. From these data it was estimated that there were about 160 individuals present in the lake.

Redhorse. Only 51 redhorse were caught, 23 were marked and released, and 26 marked fish were recaptured. From these data it was estimated that the entire population of redhorse in the lake consisted of the 23 new fish that were marked during the study. The steady decline in numbers, with no apparent recruitment, is evidence of the ultimate disappearance of this species from the population.

During this study 231 gizzard shad were taken in the nets. This number is greater than the combined total for all of the previous studies.

Of those fish, 153 were marked and released and 5 of the marked fish were recaptured. No estimate of the size of the shad population was made.

Total fishes. As during the previous study, the estimate of the size of the carp population is not considered reliable. Thus any estimate of the size and composition of the total fish population of the lake would be in error.

From the data on length frequencies and length-weight relationship gathered during the six semi-annual netting studies, along with information on which to base the estimated size and composition of the fish population, estimates were made of the total weights for each species and the population as a whole as indicated in Table 8.

Rotenone Study, April 1953

Immediately following the completion of the last semi-annual study for estimating the size and composition of the fish population of White Oak Lake, the lake was partially drained in preparation for treating it with rotenone. The use of that plant alkaloid in the eradication of fish populations has been adequately described elsewhere by Krumholz (1948) and others. By killing and recovering all the fish in the lake, an accurate appraisal of the validity of the netting estimates could be made. In addition, the data would serve as an indication of the total productivity of the lake for fish.

On April 27, parts of White Oak Creek and Melton Branch, and the whole of White Oak Lake were treated with a total of 25 gallons of emulsifiable rotenone (5 percent) with the assistance of personnel of the

Table 8. Estimates of numbers and weights, in pounds, of each species of fish large enough to be taken in the nets during each of the six semi-annual netting studies, together with the estimates of the total weight of fish, White Oak Lake, Roane County, Tennessee, 1950-1953. No estimates were made for the shad.

Kind of fish	Fall 1950		Spring 1951		Fall 1951		Spring 1952		Fall 1952		Spring 1953	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Bluegills	6,050	602	5,600	639	22,000	2,106	6,500	788	-	-	4,740	611
Black crappies	2,860	451	2,200	254	5,100	865	2,700	516	5,075	1,117	1,810	410
White crappies	1,140	180	375	43	450	76	50	12	-	-	6	2
Largemouth bass	130	250	11	20	-	-	-	-	-	-	-	-
Carp	6,450	3,450	4,825	1,549	2,550	1,790	3,100	2,062	-	-	1,700	1,552
Bullheads	250	188	390	192	875	371	350	141	488	211	161	83
Redhorse	375	375	145	145	115	115	75	78	55	60	28	34
Total	17,255	5,136	13,546	2,842	31,190	5,323	12,775	3,597	5,618	1,388	8,445	2,692

Tennessee Valley Authority, Fish and Game Branch from Norris and Paris, Tennessee. As the fish died, many of them remained at the surface, where they were picked up and carried to the dock. There, they were sorted to species and examined for marks from the netting studies. Also, scale samples, weights, and length measurements were taken from representative samples of each species. However, the majority of the fish sank to the bottom of the lake and did not rise to the surface until they became bloated. In that condition they were unfit for use in supplying accurate data on lengths and weights (Krumholz, 1951).

Assuming that all fish marked during the netting study completed in April 1953 were still in the lake, the recovery of those marked fish would furnish an indication of the completeness of the overall recovery of dead fish.

All fish that could be recovered were picked up each day for the ensuing week and these, too, were sorted, inspected for marks, and counted. By May 2, the fish remaining in the lake were at such an advanced stage of decomposition that they could not be handled easily. Accordingly, the lake level was lowered leaving the dead fish lying along the beach well above the water's edge. Under such conditions they were more readily examined for marks, and grouped according to species and lengths. All fish that were picked up were buried in an excavation well away from the shoreline on the north side of the lake.

During the period when the fish were being recovered, a large number of birds, particularly turkey vultures, along with smaller numbers of black vultures, great blue herons, kingfishers, green herons, and others were seen eating fish. The number of fish consumed by such birds is unknown.

In addition, it is known that raccoons visited the area each night and ate some of the dead fish. Perhaps other animals as well took advantage of the readily available food.

A total of 255,261 fish were handled during the study. The species composition of that total, along with the weight for each species follows:

Kind of fish	Number	Weight, pounds
Gizzard shad	210,938	13,893
Bluegills	30,814	757
Carp	8,872	7,536
Black crappies	3,398	277
Bullheads	768	240
Largemouth bass	448	465
Redhorse	23	58
Total	255,261	23,226

No white crappies were recovered during the rotenone study.

Of the 1,681 fish, exclusive of the gizzard shad and white crappies, marked during the netting study in April 1953, the following were recovered:

Kind of fish	Number marked	Number recovered	Percentage recovered
Bluegills	622	412	66.2
Carp	146	3	2.1
Black crappies	833	532	63.9
Bullheads	47	33	70.2
Largemouth bass	4	4	100.0
Redhorse	23	17	73.9
Total	1,681	1,001	

No attempt was made to check each of the gizzard shad for marks because of the tremendous numbers involved. The small number of marked carp recovered was not considered as an accurate indication of the actual recovery of that species from the lake inasmuch as most of the individuals of that species marked during the netting period were infected and some of them may have died before the rotenone study. Such a mortality among the infected fish was probably not the same as that for the remainder of the population. The numbers of marked bluegills, black crappies, largemouth bass, bullheads, and redhorse that were recovered were believed to accurately indicate the completeness of the recovery of marked fish from the lake for those species. Inasmuch as no shad were examined for marks, and the number of marked carp recovered was not indicative of the completeness of the recovery, and considering the data on the recovery of the marked fish of other species, it was assumed that the recovery of shad and carp was about 65 percent complete.

Thus, if each of the figures for the number and weight of each species of fish from White Oak Lake were multiplied by an appropriate factor to compensate for the incomplete recovery of marked fish, the estimated size of the fish population would be increased to the following values:

Kind of fish	Number	Weight, pounds
Gizzard shad	324,423	21,367
Bluegills	46,560	1,144
Carp	13,645	11,590
Black crappies	5,318	434
Bullheads	1,094	342
Largemouth bass	448	465
Redhorse	31	78
Total	391,519	35,420

The area of White Oak Lake, when filled to the 748-foot contour level, which was the most stable level maintained during the overall study, is 35.87 acres. Thus the actual number of fish recovered from the lake was 7,116 fish per acre which weighed 647.5 pounds, and the estimated total, based on the recovery of marked fish, was 10,915 fish per acre that weighed 987.5 pounds. The individual estimates of numbers and weights of fish per acre in the lake at the time it was treated with rotenone are:

Kind of fish	Number	Weight, pounds
Gizzard shad	9,046	595.7
Bluegills	1,298	31.9
Carp	380	323.1
Black crappies	148	12.1
Bullheads	30	9.5
Largemouth bass	12	13.0
Redhorse	1	2.2
Total	10,915	987.5

Although the data listed above indicate the total numbers and weights of fish present in White Oak Lake in April 1953, they include fishes of all sizes. Earlier in the report, it was mentioned that the gear used in the netting studies were selective for size inasmuch as the meshes were large enough to allow the smaller fishes to escape. The numbers and weights of fishes large enough to be retained by the nets and small enough to escape through the meshes, together with their respective totals are:

Kind of fish	Number		Weight, pounds	
	Large	Small	Large	Small
Gizzard shad	1,427	322,996	830.5	20,536.5
Bluegills	25,738	20,822	956.5	187.5
Carp	13,645	-	11,950.0	-
Black crappies	2,334	2,984	396.1	37.9
Bullheads	642	452	325.5	16.5
Largemouth bass	305	143	455.7	9.3
Redhorse	31	-	78.0	-
Total	44,122	347,397	14,632.3	20,787.7

From these data it is evident that the fish small enough to pass in and out through the meshes of the nets during the population studies made up the great majority (88.73 percent) of the total number recovered during the rotenone study. However, those small fish contributed only slightly more than half (58.69 percent) of the total recovered weight. Here, it should be pointed out that the gizzard shad were not included in any of the estimates of the population made by netting and their total numbers recovered in the rotenone study consisted primarily of members of the 1952 brood (99.56 percent) which were too small to be held in the nets. Furthermore, the shad made up 92.98 percent of the numbers and 98.79 percent of the total weight of the small fish recovered in the rotenone study. Thus, if only the other six species of fish are considered, an analysis of the data indicates that nearly two-thirds (63.63 percent) of all of the dead fish recovered were large enough to have been held in the nets, and those fish made up 98.21 percent of the total weight.

Of the total fish recovered during the rotenone study, only 11.27 percent were large enough to have been retained by the nets and those fish made up 41.31 percent of the total recovered weight.

AGE AND GROWTH OF FISH

The age and growth of the fishes of the various year classes generally reflect the well-being of the population and the ability of the different species to maintain themselves. One of the accepted methods for determining the age of a fish, its length at the end of each year of life, and its growth from year to year involves a study of the scales. This method--known as the scale method--has been in use for many years and has been adequately described by van Oosten (1923, 1929) and others. Briefly, the scale method is based on two principles: (1) each year an annulus or year mark is laid down on the scale surface, usually during the late winter or early spring, and (2) the number of scales on any fish remains constant throughout life and each scale increases in size proportional to the growth of the fish. Hence, there is a direct relationship between the size of the scale and its surface configurations and the length of the fish. The age of the fish is determined by counting the annuli, and the length of the fish at the time any annulus was formed by measuring the distance from the center of the scale through the anterior radius to the annulus in question and solving the following equation:

$$\frac{\text{Anterior radius to annulus of year X}}{\text{Total anterior radius of scale}} = \frac{\text{Length of fish at end of year X}}{\text{Length of fish when captured}}$$

Here, the length of the fish at the end of year X is the only unknown.

The distribution of the various length frequencies for any species of fish is usually of considerable value in determining the age composition of the entire population of that species. In this instance, the different modes in the length frequency curve may indicate the presence of year classes. Such distribution curves are particularly useful in analyzing the growth pattern for rapidly growing species. However, the data for length frequency distribution alone are oftentimes insufficient and the scale method must be resorted to for verification.

Scale Readings

During the course of the survey, a total of 1,896 samples of fish scales were read and analyzed for information on age and growth. Those samples were collected during the netting and rotenone studies, along with samples from all fish that were dissected in the laboratory. Each of the seven species of fish bearing scales that were large enough to be caught in the nets were represented as follows: black crappies - 765, bluegills - 591, gizzard shad - 188, white crappies - 108, largemouth bass - 92, carp - 78, and redhorse - 74. Bullheads do not have scales. The data for each species will be considered separately.

Black crappies. The calculated lengths attained by the black crappies of different ages at the time of annulus formation, are listed in Table 9. Here, it is evident that there was an apparent decrease in the calculated growth as it was determined from successively older groups of individuals (Lee's phenomenon). One of the possible explanations for this phenomenon among ciscoes (Leucicthys) given by Hile (1936) was that the more slowly growing fish survived longer than the more rapidly growing individuals. Thus, the early growth as calculated from the slow growing survivors of the older age groups would naturally be small. In fish displaying only one annulus, the average total length was 90.5 millimeters, whereas in those with two, three, and four annuli, the average lengths were 82.2, 81.2, and 80.0 millimeters, respectively. The same phenomenon is generally true for fish having two or more annuli. It must be remembered, however, that those fish having one annulus were not necessarily all members of the same year class, as one-year-old fish were caught during each of the sampling periods. Thus, the data are a composite of all year classes of black crappies in the lake at the time when they had only one annulus. The same holds true for the other groups.

Table 9. Average total lengths, together with minima and maxima, at the time of annulus formation of black crappies of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli			
	1	2	3	4
<u>One Annulus</u>				
Minimum	49			
Average	90.5			
Maximum	143			
<u>Two Annuli</u>				
Minimum	35	100		
Average	82.2	160.8		
Maximum	136	211		
<u>Three Annuli</u>				
Minimum	41	126	171	
Average	81.2	141.9	193.4	
Maximum	108	203	251	
<u>Four Annuli</u>				
Minimum	79	111	231	291
Average	80.0	126.0	238.0	303.0
Maximum	81	141	245	315

The actual measured lengths of the different year classes of black crappies collected during the six sampling periods, that were predominant in the lake during the survey, are listed in Table 10. An analysis of these data indicates that the fish of the 1951 year class were larger, on the average, at the end of their first summer of life (Fall 1951) than those of either the 1950 or 1952 year classes. In addition, that same group had a greater average length at the end of their second summer of life (Fall 1952) than those of the 1949, 1950, or 1952 year classes. This rapid growth of the 1951 year class is readily explained by the fact that the size of the 1951 brood was considerably smaller than any other brood of black crappies hatched during the survey. In contrast, the 1952 brood was the most abundant year class observed during the survey, and consequently was of the smallest average size at the end of their first summer of life. Thus, it is apparent that the size of any brood is one of the principal factors that controls the growth of the individual members of the brood.

It is also evident from the data that the fish grew during the winter months. There was a definite increase in each of the minimum, average, and maximum total lengths from all of the fall samples to those of the spring immediately following.

The maximum age of any of the black crappies taken during the survey was four years. Fish of that age were represented only in the 1946 and 1948 year classes. Only nine such individuals were observed; two in October 1950, six in the spring of 1951, and one the following spring. No such fish were taken thereafter during the netting studies or the rotenone study. Thus, of the 14,128 black crappies handled during the entire survey, only 0.06 percent had reached the age of four years.

Table 10. Average measured total lengths, together with minima and maxima, at the time of collection, of black crappies of the different year classes, White Oak Lake, Roane County, Tennessee, 1950-1953

	Collection Period					
	Fall 1950	Spring 1951	Fall 1951	Spring 1952	Fall 1952	Spring 1953
1949 Year Class						
Minimum	131	147	178	189	194	198
Average	152.2	158.1	195.0	199.8	205.6	210.0
Maximum	175	178	212	216	235	235
1950 Year Class						
Minimum	96	103	151	152	176	179
Average	105.2	111.2	170.6	174.9	193.9	195.5
Maximum	111	117	185	197	257	228
1951 Year Class						
Minimum			105	107	156	168
Average			123.3	125.7	173.8	174.6
Maximum			141	144	187	189
1952 Year Class						
Minimum					76	93
Average					101.4	113.3
Maximum					126	128

In a study of the age and growth of the black crappies in Norris Reservoir, Tennessee, based on 677 specimens captured by various methods, Stroud (1948) found that 47 individuals were four years old and one had reached an age of five years. It was further stated (Stroud, op. cit.) that 18.6 percent of a sample of 194 black crappies caught by anglers from the same body of water were four-year-olds. If the data from White Oak Lake were rearranged to include only those fish large enough to be of interest to anglers (seven inches), it is found that only nine of 4,870 individuals (0.18 percent) reached an age of four years.

Information on the age and growth of black crappies from Cherokee and Douglas Reservoirs, Tennessee, and Hiwassee Reservoir, North Carolina, (Stroud, 1948) indicates that the life span for that species in those waters was about the same as for Norris.

The black crappies in White Oak Lake grew more slowly on the average, with the possible exception of the first year, than in any of the nearby waters of the Tennessee Valley Authority as indicated by the following data:

Body of water	Average lengths at end of year			
	1	2	3	4
White Oak Lake	3.6	6.3	7.6	11.9
Norris Reservoir	2.5	9.2	11.5	12.7
Hiwassee Reservoir	2.9	7.5	10.2	11.5

From these data it is apparent that the black crappies grow more slowly and their life span is considerably shorter, perhaps by as much as 25 or 30 percent, than in some larger bodies of water nearby.

Bluegills. The average total lengths, together with the minima and maxima, of bluegills of different ages, calculated from scale readings, are listed in Table 11. These data indicate that the same phenomena of age and growth are present for the bluegills as were found among the black crappies. Here, again, it is apparent that the slowly growing fish lived longer than the others. Fish having only one annulus had an average total length of 42.0 millimeters, whereas those with two, three, four, and five annuli were 39.0, 36.3, 28.4, and 28.1 millimeters long respectively. Similar trends are evident among the older fish with the single exception of the five-year-old fish at the time of the formation of the fourth annulus. The reason for this discrepancy is not obvious.

Although only limited data are available from Chickamauga Reservoir, and none from the other waters, the bluegills apparently grow more slowly in White Oak Lake as indicated by the following figures:

	Average lengths at end of year				
Body of water	1	2	3	4	5
White Oak Lake	1.7	3.6	5.0	5.5	6.6
Chickamauga Reservoir	2.0	4.8	5.5		

The actual lengths of the individuals of the various year classes at the time of capture, together with the minimum and maximum lengths in the size range for each of the six semi-annual periods are listed in Table 12. Here, too, as among the black crappies, it is evident that the bluegills grew during the winter months. The maximum age of any bluegill taken during the survey was five years. Unfortunately, there are no published data on the age and growth of bluegills for any of the Tennessee Valley waters except those listed above.

Table 11. Average total lengths in mm, together with minima and maxima, at the time of annulus formation of bluegills of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli				
	1	2	3	4	5
One Annulus					
Minimum	16				
Average	42.0				
Maximum	96				
Two Annuli					
Minimum	19	48			
Average	39.0	91.5			
Maximum	70	136			
Three Annuli					
Minimum	20	46	101		
Average	36.3	84.4	127.6		
Maximum	67	114	160		
Four Annuli					
Minimum	14	42	77	113	
Average	28.4	66.6	113.1	138.8	
Maximum	51	108	145	176	
Five Annuli					
Minimum	21	46	81	124	157
Average	28.1	64.4	106.6	141.4	168.4
Maximum	51	82	133	164	183

Table 12. Average measured total lengths, together with minima and maxima, at the time of collection, of bluegills of the different year classes, White Oak Lake, Roane County, Tennessee, 1950-1953

	Collection Period						
	Fall 1950	Spring 1951	Fall 1951	Spring 1952	Fall 1952	Spring 1953	
1947 Year Class							
Minimum	132	128	155	147	175	178	
Average	133.3	134.7	166.1	166.8	183.3	189.4	VI
Maximum	167	168	174	176	194	195	
1948 Year Class							
Minimum	111	116	133	132	151	156	
Average	126.4	129.3	144.8	148.0	158.5	162.9	V
Maximum	149	144	170	176	164	167	
1949 Year Class							
Minimum	110	111	110	105	126	144	
Average	118.5	118.6	133.6	138.3	143.5	148.6	IV
Maximum	125	125	159	162	168	164	
1950 Year Class							
Minimum			105	105	98	110	
Average			115.2	117.1	126.0	130.3	III
Maximum			130	132	163	158	
1951 Year Class							
Minimum					89	80	
Average					107.5	112.0	II
Maximum					151	156	

White crappies. The white crappie, although closely related to the black crappie, grew more slowly than the latter throughout the survey. Nearly all of the data on the age and growth of the white crappie were gathered during the first two semi-annual netting studies. The average calculated lengths of the white crappies of different ages, based on scale readings, along with the minimum and maximum measurements to indicate the range in length, are listed in Table 13. No minima or maxima are listed for the single fish with four annuli. The maximum age of any white crappie taken during the study was four years.

In Douglas and Cherokee Reservoirs, Stroud (1949) found that the white crappie grew faster than the black crappie, whereas the growth of the white crappie was about the same as that of the black crappie in Norris. In White Oak Lake, the rate of growth of the white crappie was slower than in any of the nearby reservoirs, for all years of life except the first, as shown by the following data:

	Average lengths at end of year		
Body of water	1	2	3
White Oak Lake	3.4	5.4	6.9
Cherokee Reservoir	1.5	8.7	11.6
Douglas Reservoir	2.9	7.3	9.2
Hiwassee Reservoir	2.4	6.8	9.5
Chickamauga Reservoir	2.4	5.6	8.0

Largemouth bass. Most of the samples of scales from largemouth bass were taken during the fall of 1950 and the spring of 1953; only very few being caught during the intervening netting periods. The average total lengths for largemouth bass, together with the minima and maxima,

Table 13. Average total lengths, together with minima and maxima, at the time of annulus formation of white crappies of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli			
	1	2	3	4
One Annulus				
Minimum	45			
Average	85.3			
Maximum	130			
Two Annuli				
Minimum	32	85		
Average	64.6	136.1		
Maximum	107	180		
Three Annuli				
Minimum	30	94	114	
Average	44.5	116.1	176.1	
Maximum	97	163	231	
Four Annuli				
Minimum				
Average	22	67	115	162
Maximum				

calculated from scale readings, are listed in Table 14. Similar growth phenomena as those described for the black crappie are again in evidence.

In his study of the growth of the largemouth bass in Norris Lake, Stroud (1948) stated "... it is probable that a large proportion of Norris largemouth die of 'old age' before reaching the age of 5 years, although a few live as long as 7 years or even longer." Of 748 largemouth bass of all sizes studied by Stroud, he found 50 individuals (6.4 percent) that were five years old or older. In the present study, where scales from a highly selected group of 92 bass of all sizes were analyzed, there were no fish that were more than five years old, and only six (6.5 percent) that had reached that age. Here, again, there is evidence that the life span of the largemouth bass in White Oak Lake is shorter than it is in one of the nearby TVA reservoirs.

A comparison of the growth of the largemouth bass in White Oak Lake with that in one of the nearby reservoirs indicates that the species grows more slowly in White Oak Lake as shown by the following data:

	Average lengths at end of year					
Body of water	1	2	3	4	5	6
White Oak Lake	4.0	9.3	13.0	16.0	16.9	
Norris Reservoir	6.9	12.2	14.6	16.2	17.5	19.3

Carp. The average calculated total lengths, together with the minima and maxima to indicate the size range, of carp of different ages, based on scale readings, are listed in Table 15. Lee's phenomenon as described for the black crappies is not so clearly defined among the carp, especially in the one-year-old fish. The oldest carp among the scale

Table 14. Average total lengths, together with minima and maxima, at the time of annulus formation of largemouth bass of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli				
	1	2	3	4	5
One Annulus					
Minimum	63				
Average	102.6				
Maximum	163				
Two Annuli					
Minimum	55	129			
Average	100.4	238.6			
Maximum	181	371			
Three Annuli					
Minimum	49	120	203		
Average	91.9	232.5	329.6		
Maximum	132	385	441		
Four Annuli					
Minimum	62	167	242	259	
Average	80.9	239.7	351.2	406.1	
Maximum	103	341	438	484	
Five Annuli					
Minimum	32	103	237	304	383
Average	50.8	159.7	293.3	372.0	429.2
Maximum	75	234	370	427	453

Table 15. Average total lengths, together with minima and maxima, at the time of annulus formation of carp of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli				
	1	2	3	4	5
One Annulus					
Minimum	71				
Average	123.9				
Maximum	173				
Two Annuli					
Minimum	28	119			
Average	90.6	175.7			
Maximum	151	208			
Three Annuli					
Minimum	30	115	140		
Average	93.2	162.1	226.7		
Maximum	144	228	300		
Four Annuli					
Minimum	32	97	153	170	
Average	98.6	157.6	231.2	264.0	
Maximum	169	239	351	413	
Five Annuli					
Minimum	45	90	126	187	213
Average	52.5	95.0	127.0	189.5	213.5
Maximum	60	100	128	192	214

samples studied was in its sixth year of life (five annuli). However, there were fish that were considerably larger than the five-year-olds recovered during the rotenone study. The scales of those fish could not be read with certainty.

Redhorse. The growth phenomena described for the black crappie are manifest in the data for the redhorse (Table 16). Although these data indicate the presence of fish of three different ages, the majority of them belonged to the same year class (1949) and scale samples were taken from them during the successive netting studies. The growth rate for the redhorse was rapid during the first two years and slowed down thereafter. The oldest redhorse recorded during the survey were members of the 1949 year class which were beginning their fifth year of life when killed in April 1953.

Gizzard shad. The calculated minimum, average, and maximum total lengths of gizzard shad of different ages, based on scale readings, are listed in Table 17. In overall length attained, the shad was the fastest growing species in the lake; the one-year-olds having reached an average total length of 9.5 inches by the time they formed their first annuli. The maximum life span of the gizzard shad in White Oak Lake appear to be between three and four years. An examination of scales from a few shad which died during the mortality in the winter of 1950-1951, indicated that those fish were in their fourth year of life (three annuli). The oldest fish taken during the netting and rotenone studies was also shown by scale readings to have been in its fourth year of life.

Table 16. Average total lengths, together with minima and maxima, at the time of annulus formation of redhorse of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli			
	1	2	3	4
One Annulus				
Minimum	No fish taken			
Average	No fish taken			
Maximum	No fish taken			
Two Annuli				
Minimum	82	197		
Average	177.6	261.0		
Maximum	246	303		
Three Annuli				
Minimum	68	144	215	
Average	125.2	215.5	283.8	
Maximum	200	263	337	
Four Annuli				
Minimum	48	121	224	289
Average	121.6	203.9	277.0	325.6
Maximum	186	263	324	374

Table 17. Average total lengths, together with minima and maxima, at the time of annulus formation of gizzard shad of different ages, calculated from scale readings, White Oak Lake, Roane County, Tennessee, 1950-1953

	Number of annuli		
	1	2	3
One Annulus			
Minimum	186		
Average	240.8		
Maximum	291		
Two Annuli			
Minimum	169	242	
Average	225.5	293.4	
Maximum	276	334	
Three Annuli			
Minimum	138	216	269
Average	174.0	242.0	291.5
Maximum	208	268	314

Length-frequency Distribution

All fish caught during the netting studies were measured to total length to the nearest millimeter. In assembling the data for length frequencies, the lengths were placed in either half-inch or quarter-inch groups. Each quarter-inch group included measurements on those fish whose lengths were between one-eighth inch smaller and one-eighth inch larger than the quarter-inch around which the group was centered. Similarly, the half-inch groups included those measurements in the range from one-fourth inch smaller to one-fourth inch larger than the half-inch which served as a center for the group. Such fractional measurements of inches as were necessary were made to the nearest millimeter. Thus, the quarter-inch group for five inches (127 millimeters) included those measurements between 125 and 130 millimeters inclusive, whereas the half-inch group for five inches included those lengths between 121 and 133 millimeters inclusive.

The data for the bluegills, black crappies, and white crappies were assembled into quarter-inch groups, and those for the other five species into half-inch groups. In the cases of the black crappies, bluegills, carp, and bullheads, there were sufficient data on which to base percentage frequencies of the different size groups for graphic presentation as illustrated in Figures 2, 3, 4, and 5 respectively. The data for the white crappies, largemouth bass, redhorse, and gizzard shad were inadequate for such treatment and the numbers of those fish measured during the survey are listed in Tables 18, 19, 20, and 21 respectively.

In the length-frequency histograms for the black crappies and bluegills, the figures that correspond to the various year classes have been inserted above the appropriate length for each sampling period. These data

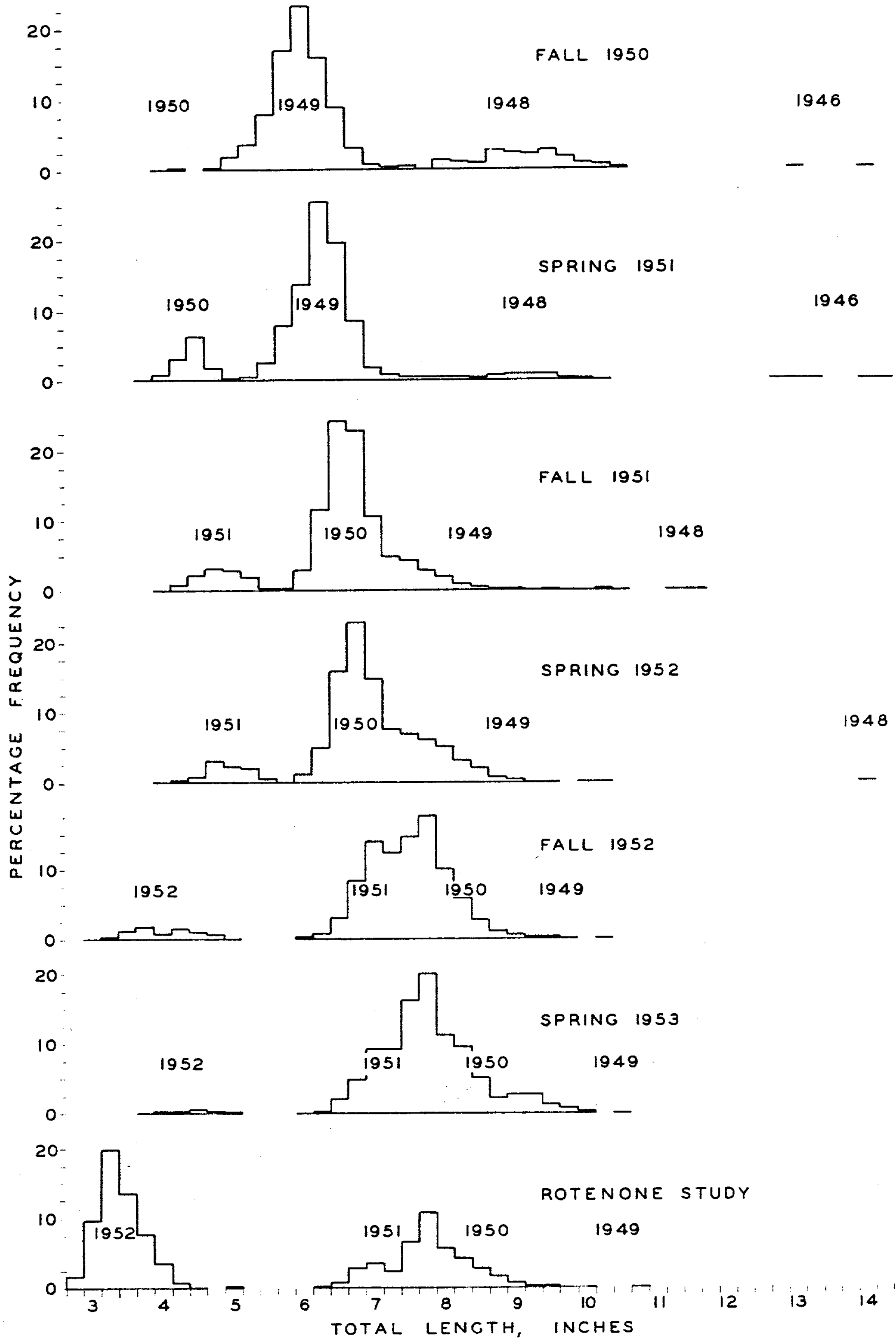


FIGURE 2. LENGTH FREQUENCIES OF BLACK CRAPPIES, WHITE OAK LAKE

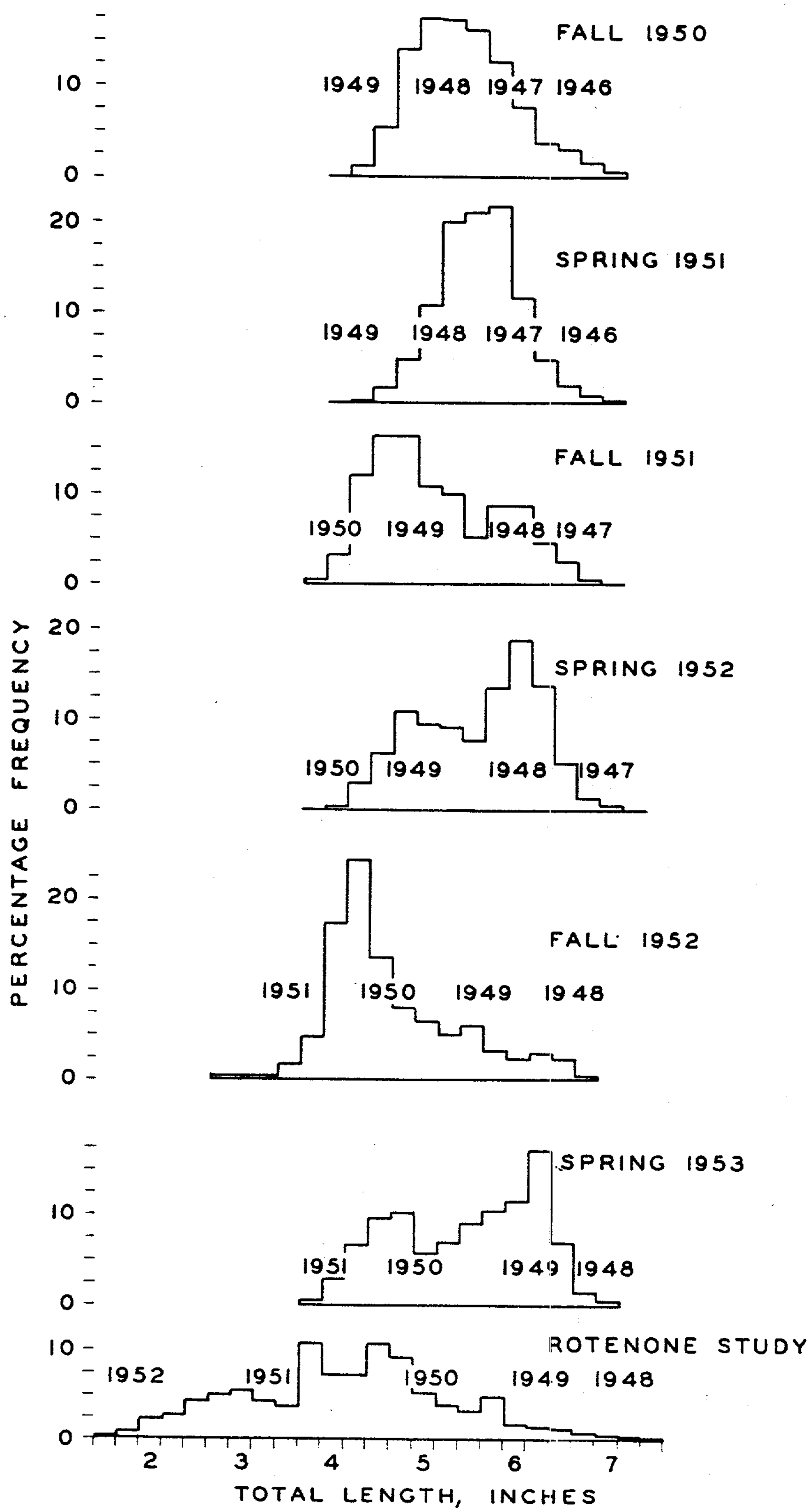


FIGURE 3. LENGTH FREQUENCIES OF BLUEGILLS, WHITE OAK LAKE

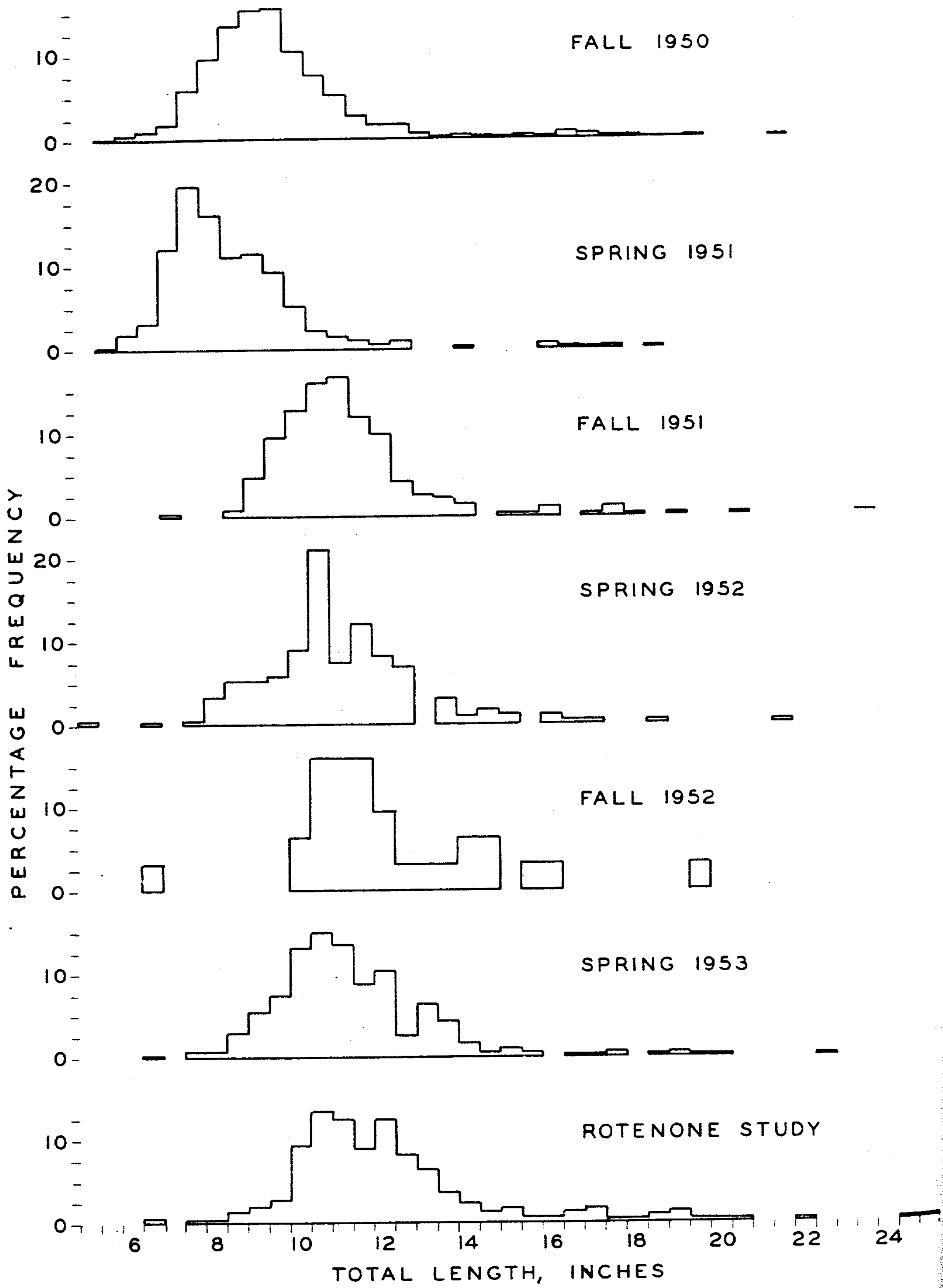


FIGURE 4. LENGTH FREQUENCIES OF CARP, WHITE OAK LAKE

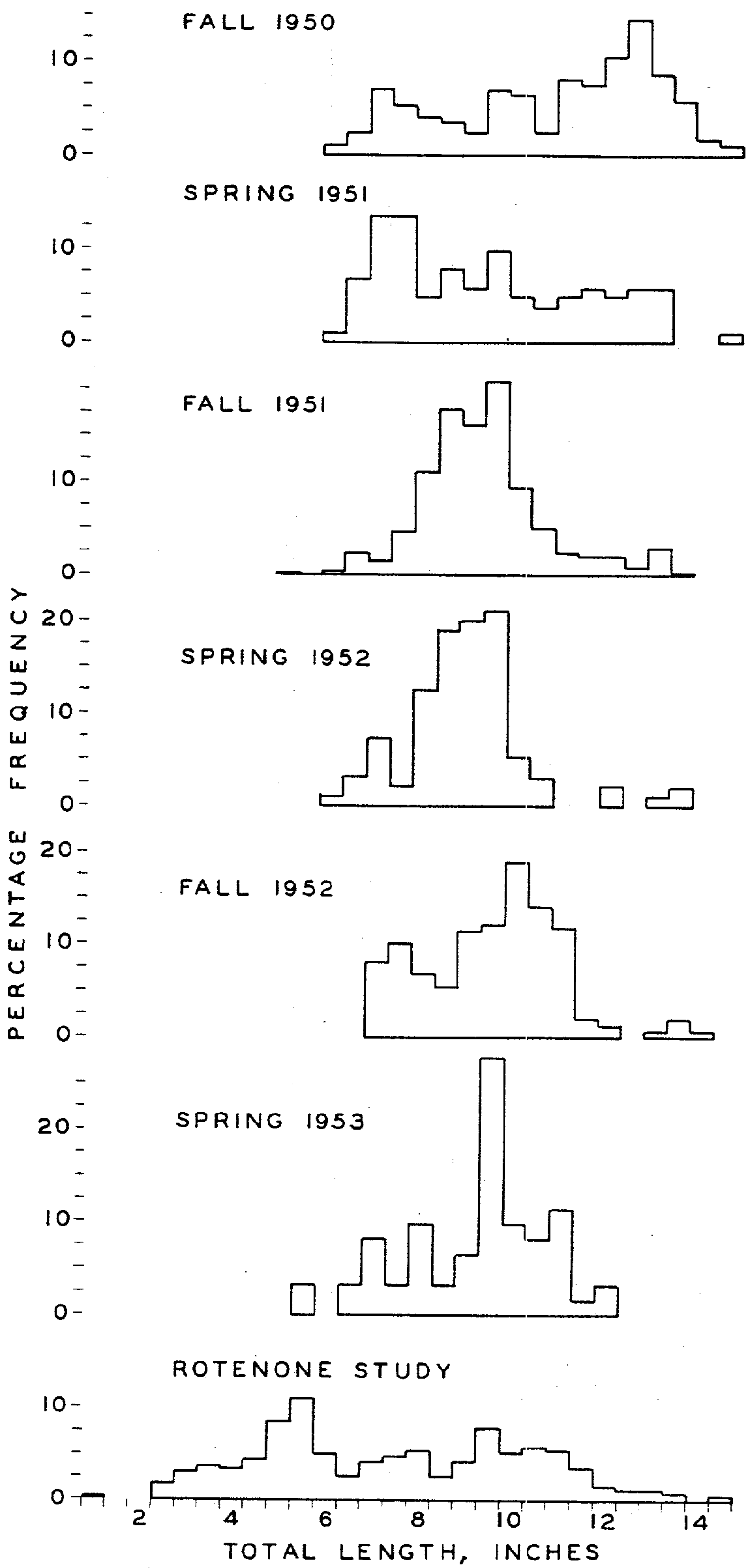


FIGURE 5. LENGTH FREQUENCIES OF BULLHEADS, WHITE OAK LAKE

Table 18. Numbers of white crappies, arranged according to total length in quarter-inch groups, measured during the six semi-annual studies for estimating the size and composition of the fish population of White Oak Lake, Roane County, Tennessee, 1950-1953, together with similar data from the rotenone study, April 1953

Size group (inches)	Fall 1950 Number	Spring 1951 Number	Fall 1951 Number	Spring 1952 Number	Fall 1952 Number	Spring 1953 Number	Rotenone 1953 Number
4.25		1	1				
4.50		7	1				
4.75		3	1				
5.00	3	1	10				
5.25	3	5	7	2			
5.50	8	11	5	1			
5.75	17	52	2	1			
6.00	13	59	2				
6.25	3	78	12	4			
6.50	5	52	12	1			
6.75	5	23	31	9			
7.00	5	16	27	5			
7.25	1	11	12	3			
7.50	2	7	6	17			
7.75	2	5	6	4		1	
8.00		1	2	3			
8.25	1	2	2	5	1	2	
8.50	1		1				
8.75	1	2	2	2			
9.00	2	2					
9.25		1	2	1		1	
9.50	1	1	1	2			
9.75		3	1		2		
10.00	1					2	
10.25		1					
10.50							
10.75							
11.00	1						
Total	75	344	146	60	3	6	0

Table 19. Numbers of largemouth bass, arranged according to total length in half-inch groups, measured during the six semi-annual studies for estimating the size and composition of the fish population of White Oak Lake, Roane County, Tennessee, 1950-1953, together with similar data from the rotenone study, April 1953

Size group (inches)	Fall 1950 Number	Spring 1951 Number	Fall 1951 Number	Spring 1952 Number	Fall 1952 Number	Spring 1953 Number	Rotenone 1953 Number
3.5							3
4.0							3
4.5							4
5.0							4
5.5							6
6.0							3
6.5							6
7.0							2
7.5							
8.0	1						
8.5	5						
9.0	8						2
9.5							
10.0	4				3		6
10.5	3		1		2		9
11.0	3					1	4
11.5	2			1		2	5
12.0	8						4
12.5	6		1				4
13.0	3						3
13.5		1				1	4
14.0	3						5
14.5	2			1			3
15.0	2			1			2
15.5	2		1				1
16.0	1			3			3
16.5	2	1		1			2
17.0	2	2	1				1
17.5			4	2			2
18.0	2		1	2			
18.5	1		1	2			
19.0	2						1
19.5				1			2
20.0							1
Total	67	4	10	14	5	4	97

Table 20. Numbers of redhorse, arranged according to total length in half-inch groups, measured during the six semi-annual studies for estimating the size and composition of the fish population of White Oak Lake, Roane County, Tennessee, 1950-1953, together with similar data from the rotenone study, April 1953

Size group (inches)	Fall 1950 Number	Spring 1951 Number	Fall 1951 Number	Spring 1952 Number	Fall 1952 Number	Spring 1953 Number	Rotenone 1953 Number
7.0		1					
7.5	5	1	1				
8.0							
8.5							
9.0	2	1					
9.5				1			
10.0	2						
10.5	1	2		1	1		
11.0	23	6	1	2			
11.5	57	6	11	2		1	
12.0	44	26	14		2		
12.5	24	21	21	8	2	2	
13.0	3	1	29	16	5	3	2
13.5			35	19	12	5	2
14.0			12	17	11	5	3
14.5	1		1	4	12	23	5
15.0					5	12	3
15.5					2		1
Total	162	65	190	69	52	51	16

Table 21. Numbers of gizzard shad, arranged according to total length in half-inch groups, measured during the six semi-annual studies for estimating the size and composition of the fish population of White Oak Lake, Roane County, Tennessee, 1950-1953, together with similar data from the rotenone study, April 1953

Size group (inches)	Fall 1950 Number	Spring 1951 Number	Fall 1951 Number	Spring 1952 Number	Fall 1952 Number	Spring 1953 Number	Rotenone 1953 Number
4.5							1
5.0					3		8
5.5					11	27	76
6.0					13	27	40
6.5			1		5	19	17
7.0					5	8	4
7.5			4	1	1		
8.0			16	3			
8.5			16	9			
9.0			27	11	1	1	
9.5			15	10		1	
10.0			4	8	4	6	
10.5	2		1	6	13	18	3
11.0				2	6	37	10
11.5			1		5	29	9
12.0		1	1		4	18	5
12.5					5	14	9
13.0					1	6	1
13.5				1	1	1	2
14.0				2	2		2
14.5				3	1		
15.0				1	1	1	
15.5				3	1		
16.0				3			
Total	2	1	86	63	83	213	187

for the black crappies indicate that the 1950 year class comprised the major portion of the population in the fall of 1951 and the spring of 1952, and, to a lesser extent during the next two netting periods. However, by the spring of 1953, the 1950 year class had largely been supplanted by that of 1951. The 1952 year class was probably the largest single year class of black crappies present in the lake during the survey. Members of that class made up approximately 56 percent of the total numbers of black crappies recovered during the rotenone study.

Among the bluegills there was no particular year class that was outstanding during the survey period. Members of each of the 1947, 1948, 1949, 1950, and 1951 made up the major part of the total bluegill population at one time or another during the study. However, because of their relatively slow growth as compared with the black crappies, the fish were usually about two years old when first taken in the nets.

So far as the data for the carp and bullheads are concerned, it was not practicable to assign year classes to the length frequencies in the histograms. The relatively great size ranges for each year class of carp precluded any assignment of a particular class to any part of the histogram. No attempt was made to determine the ages of the bullheads.

An examination of the data for the white crappies indicates that the species was gradually disappearing from the lake.

The reason for the relatively large catch of largemouth bass during the first netting study as compared with the catches from later studies is not obvious. It may be, however, that the lake water was so turbid during the first study that the fish could not see the nets and thus could not avoid them. During the last five studies the water was much clearer and the visibility much better.

From the data on the redhorse it is obvious that the majority of the fish sampled during the six netting periods, and also during the rotenone study, were members of the same year class. This observation is borne out by the scale readings. For some unknown reason the redhorse did not reproduce successfully after 1949.

Following the heavy winter mortality of large gizzard shad in 1950-1951, the remaining fish apparently spawned successfully, and young-of-the-year fish were prominent in the fall catch of 1951 and thereafter during the study. Members of the 1952 year class were taken during the fall study in 1952, but their average length was considerably less than that of the 1951 year class (Table 21).

Length-weight Relationship

The relationship between the length and weight of any fish is generally used as an indication of "condition" or plumpness. The average weight in grams of bluegills, black crappies, and white crappies of different length groups are listed in Table 22. From these data it is obvious that the bluegills were much heavier for their length than were either of the crappies. However, the black crappies were consistently heavier in each length group than the white crappies of comparable size.

The average weights in grams of the largemouth bass, carp, bullheads, and gizzard shad of different total length groups are listed in Table 23. Here, it is indicated that up to the maximum size taken, the bullheads were heaviest and the shad lightest for their lengths. The carp were heavier than the bass at all lengths up to 10.5 inches, whereas at

Table 22. Average weights of bluegills, black crappies, and white crappies of different quarter-inch groups, White Oak Lake, Roane County, Tennessee

Size group (inches)	Weight in grams		
	Bluegills	Black crappies	White crappies
1.50	1.0		
1.75	1.6		
2.00	2.2		
2.25	3.2		
2.50	4.5	2.8	
2.75	6.1	3.9	
3.00	8.7	5.6	
3.25	10.7	7.6	
3.50	14.0	9.7	
3.75	18.2	11.9	
4.00	22.2	14.6	
4.25	26.6	17.3	12.0
4.50	31.2	20.4	14.7
4.75	36.6	24.1	18.5
5.00	44.4	27.7	22.6
5.25	50.8	32.0	26.0
5.50	57.2	36.9	30.6
5.75	66.3	41.8	35.2
6.00	71.8	47.0	40.3
6.25	82.0	53.8	46.5
6.50	92.8	59.8	52.5
6.75	104.5	67.1	59.1
7.00	119.5	73.0	67.5
7.25	132.3	83.6	75.2
7.50	146.0	94.0	84.0
7.75		105.8	95.0
8.00		116.0	105.8
8.25		128.6	119.0
8.50		141.6	131.8
8.75		153.4	145.0
9.00		178.0	162.0
9.25		195.5	177.5
9.50		217.0	193.8
9.75		240.0	213.1
10.00		272.5	230.0

Table 23. Average weights of largemouth bass, carp, bullheads, and gizzard shad of different half-inch groups, White Oak Lake, Roane County, Tennessee. The figures in parentheses for gizzard shad were taken from a curve; no actual weights were available.

Size group (inches	Weight in grams			
	Largemouth bass	Carp	Bullheads	Gizzard shad
2.5			3.5	
3.0			5.0	
3.5			7.6	
4.0			11.4	
4.5	12.6		15.8	10
5.0	19.4		24.0	19
5.5	26.1		34.2	28
6.0	34.2	68	45.5	37
6.5	47.5	79	57.0	47
7.0	52.4	91	70.0	58
7.5	78.9	110	88.0	(69)
8.0	96.0	125	109.3	(81)
8.5	117.0	145	132.7	(95)
9.0	140.0	166	175	(110)
9.5	166.0	190	210	(127)
10.0	201.5	215	291	(147)
10.5	240.2	245	356	171
11.0	282.0	278	467	198
11.5	328.4	316		233
12.0	390.0	365	652	274
12.5	444.0	412		319
13.0	520.0	467	765	370
13.5	602.0	528		427
14.0	697.5	592	850	490
14.5	795	656		
15.0	900	735		
15.5	1014	813		
16.0	1120	898		
16.5	1248	992		
17.0	1358	1088		
17.5	1468	1185		
18.0	1575	1292		
18.5	1700	1408		
19.0	1818	1527		
19.5	1940	1645		
20.0	2060	1758		
20.5		1900		
21.0		2025		
21.5		2155		
22.0		2285		
22.5		2420		
23.0		2540		
23.5		2670		
24.0		2800		
24.5		2925		
25.0		3055		

lengths greater than 11 inches the bass were consistently heavier. No length-weight relationship was prepared for the redhorse.

Inasmuch as all fish caught during the netting studies were measured to total length, estimates of the total weight of fish in the lake were made for each study by applying the average weights as outlined in the above tables.

Discussion

The fish population of White Oak Lake is believed to be essentially the same as that of any comparable body of water in the region. Although there are a number of large reservoirs nearby, which differ considerably from White Oak Lake in their physical and biological characteristics, there are no such impoundments of smaller size that have been studied. However, some information from the larger waters, such as that on age and growth of fishes, is useful as a guide. Inasmuch as no comparable data on fish populations are available, much of the discussion will of necessity be based on general information that has been accumulated over many years from a variety of sources. The methods and practices used in collecting the data for making estimates of the size and composition of the fish population, whether by netting studies or rotenone, have become well established and generally accepted in the field of fishery biology. Still, there is much to be learned about the overall dynamics of fish populations, their fluctuations, both interspecific and intraspecific, which are brought about by pressures exerted by one species against another or by one year class of a particular species against the other year classes of the same species, the interdependence or antagonism of the different species concerned, together with the general picture of the ability of the different components of a fish population to maintain themselves.

The general fertility and productivity of White Oak Lake are believed to be much higher than most other lakes of the region. The primary cause of that increased fertility is that the lake receives all the treated domestic sewage effluent from the Oak Ridge National Laboratory. Thus, in White Oak Lake there is essentially the same condition of increased fertility and productivity as there would be for any body of water, about 35 acres in extent, that received the sewage effluent from a municipality with a population of about 3,000 people. Any increase in fertility usually results in an increased productivity in any body of water. However, the increased fertility in itself cannot be held directly responsible for any changes in the species composition of the fish population. Changes in the populations of planktonic and other invertebrate organisms may result directly from increases or decreases in the amount of certain elements or nutrient materials, whereas changes in the species composition of the fish populations are usually traceable to marked changes in habitat, food supply, chemical characteristics of the water, etc.

It is not known what changes in the size and species composition of the fish population of White Oak Lake took place during the first seven years of impoundment (1943-1950). However, the composition of the fish population in White Oak Lake was considerably different from that of Watts Bar Reservoir, of which it was originally a part, at the beginning of the survey. Much silting has occurred in the basin of White Oak Lake since its impoundment in 1943. This in itself is a major deterrent to the well-being of any fish population. Since the advent of the survey in 1950, there have been marked changes in the species composition, so it can safely be assumed that other changes must have taken place prior to that time. All the survey did was to take note of the changes which took place over a period of three years.

Several general conclusions may be drawn from the results of the six semi-annual netting studies. First, there is confirmation of the fact that the gear used was highly selective for certain species of fish in the lake. The vulnerability of both species of crappies was exceptionally high, about twice that of the bluegills which were readily caught during most of the netting studies. The carp, on the other hand, were not very easily caught, probably because the physical contour of the lake bottom precluded the placement of nets where the large concentration of that species were known to occur. The bullheads and redhorse were usually taken in sufficient numbers on which to base what are believed to have been fairly good estimates of the size of those particular populations. So far as the largemouth bass are concerned, that species has long been known to be difficult to capture in passive netting devices. The reasons for not having made any estimates of the size of the population of gizzard shad have been discussed previously.

Second, although the last two netting studies failed to yield adequate data on which to base sound estimates, the first four studies did indicate that there was a definite decrease in the overall weight of the fish population over winter. That same phenomenon of decreased carrying capacity during the colder months of the year has been discussed by Krumholz (1948) in a preliminary report on the fish populations in ponds at Wolf Lake Hatchery in Michigan and at the Maxinkuckee Experiment Station in

Indiana. In further studies along the same line in Indiana, which were completed during the author's tenure with the present survey (unpublished data), it was shown that there was an average decrease of about 20 percent in the weight of the total population each winter with the exception of three individual cases in which populations of only one species, either bluegills or largemouth bass, were involved. In those experiments, each of five ponds that had been stocked at known rates with various combinations of largemouth bass, bluegills, black crappies, and bowfin (*Amia calva*) were drained each fall and spring for six summers and the intervening winters, and all of the fish were recovered, counted, weighed, and measured to total length. Following such periods of over-winter decrease, there was always an increase in the weight of the population during the ensuing summer to a level similar to that of the preceding fall. In three other ponds at the same experiment station, used for similar studies for periods of from two to four years, and which were stocked with combinations of the same species, the same phenomenon was observed. In still another pond, stocked with hybrid offspring of male bluegills and female redear sunfish and observed for three years, the same sort of seasonal fluctuations in the weight of the population were observed. Thus, the occurrence of an over-winter decrease in the weight of a total fish population followed by an increase of complementary proportions during the ensuing summer, was observed in 38 of 41 instances. Such an overwhelming majority pretty well establishes the fact that such seasonal changes must be an integral part of the normal picture of the natural dynamics of fish populations. From this it seems reasonable to conclude that, even though the estimates based on the netting studies may not have been quantitatively accurate, they certainly provided qualitative information that followed an established pattern.

In considering the estimates for the fall of 1950 and the spring of 1951, it appears that there was an over-winter decrease of nearly 45 percent. During the following winter there was a decrease in estimated weight of about 32 percent. These two figures are considerably higher than the average observed decrease in the Indiana ponds. However, the range in decrease in the Indiana ponds was from about 3 to 47 percent. The maximum estimated weights in the fall for the fish population of White Oak Lake were very similar both years (Table 8). The greater decrease during the winter of 1950-1951 may have been the result of the effects of the relatively severe winter. During that time the lake was completely covered with about an inch of ice for a period of about five weeks, the only period during the survey when the entire lake has been so covered. The experimental fish populations observed in Indiana were similar to the population in White Oak Lake during the survey period in that there was no exploitation of the fishery.

Third, there is substantial evidence that all species of fish grew appreciably during the winter months as indicated by the increased average lengths in the spring netting studies over those of the preceding fall. This same phenomenon was observed by Krumholz (unpublished data) in populations of fish in ponds in northern Indiana.

Neither of the last two estimates of the total size and composition of the fish population in White Oak Lake are reliable. Thus, it is impossible to compare the quantitative estimates of the netting studies with the data from the rotenone study. There is no obvious reason why the same nets in the same locations which caught fish during the first four studies should fail to do so during the last two. There were no changes in the techniques or methods of operation. However, the fact remains that during two of the six semi-annual netting studies, the numbers of fish caught were inadequate to serve as bases for estimating the size and composition of (some species) the fish population. Such inconsistencies in results from a routine procedure point up the fact that there is much to be learned about the normal fluctuations and interrelationships of fish populations.

The data for age and growth of the bluegills, black crappies, and largemouth bass from White Oak Lake indicate that those fish did not grow as fast as individuals of the same species in nearby reservoirs of the Tennessee Valley Authority. Furthermore, there is substantial evidence that the life spans of the black crappie and largemouth bass, which spent their entire lifetime in White Oak Lake, were considerably shorter than those of the same species in Norris Reservoir and perhaps other nearby impoundments as well. In the histogram of the length-frequency distribution of the black crappie (Figure 2), it is apparent that the members of the 1950 year class, which first appeared in the catch in October 1950, and constituted the major portion of the catch a year later, had largely been supplanted in the spring catch of 1953 by individuals of other year classes. None of the other year classes fared any better. Furthermore, the evidence from scale readings shows that only a very small number of individuals of that species attain an age of four years. Thus it seems reasonable to conclude that the maximum life span for black crappies in White Oak Lake is about three years. It will be shown elsewhere in this report that the fish living in White Oak Lake are constantly exposed to certain low level external doses of radiation. Also, they accumulate and incorporate into their tissues rather large amounts of radioactive materials. Thus, they receive a constant internal as well as external dose of radiation. It has been shown by other workers that exposure to radiation tends to reduce longevity. Hence, a shortening of the life span of the black crappies, and perhaps all other species of fish in White Oak Lake as well, is probably a "natural" occurrence.

In studying the scales of fishes from White Oak Lake it was found that the time of annulus formation ranged from early May until late July. In general, the smaller fish formed their annuli earlier in the summer than did the older individuals. A few fish which were collected in August had not yet formed an annulus that year. An examination of those scales disclosed that the fish could not have attained their current size and still belong to the same year class. It may be that in this particular instance of three-year-old fish that they just hadn't formed an annulus that year.

If it is assumed that the annulus is laid down early in the summer, say May or June, an examination of the data for the calculated and actual measured lengths of black crappies (Tables 9 and 10) will show that the actual lengths of the fish taken during the spring netting studies were considerably greater than the calculated lengths for the same groups of fish. For instance, the greatest average calculated length at the time of formation of the first annulus was 90.5 millimeters as compared with an average measured length of 113.0 millimeters for the individuals of the 1952 year class at the time of the rotenone study in April 1953. Here, it should be pointed out that the 1952 year class was smaller in average length at that age than any of the other year classes of black crappies observed during the survey, and that the measured lengths were recorded at least a month before the assumed time of annulus formation. Thus, there is a difference between the two lengths of about 23 millimeters. It is well known that small fish are scaleless for a certain period of time early in life. If the black crappies did not begin to form scales until they were slightly less than an inch in length, the discrepancy between the calculated and measured lengths referred to above could largely be accounted for by adding the length of the fish before it formed any scales, to the calculated length at the time of formation of the first annulus. Much the same sort of information can be obtained by examining the data for the calculated and measured lengths of the bluegills from White Oak Lake (Tables 11 and 12).

During the course of the survey, two species of fish, the white crappie and the redhorse, gradually diminished in total numbers. When the fish population was killed with rotenone in April 1953, no white crappies were recovered even though a special effort was made to find some. During the first two netting studies, well over 200 individual white crappies were caught, and the number estimated to have been present in April 1951 was more than 1,100 individuals. Although a small amount of recruitment to the population took place through natural reproduction, the population completely disappeared within the next two years. As for the redhorse, much the same kind of mortality took place except in a more gradual manner. A total of 17 redhorse, which represented 74 percent of the fish marked during the netting study in April 1953, were recovered later that month during the rotenone study. No appreciable recruitment to the population of redhorse had taken place through reproduction during the three-year period of the survey.

The recovery, during the rotenone study, of approximately 60 percent of the fish that had been marked several weeks previously during the spring netting study is very good when the tremendous numbers of fish involved and the limited time available for recovering them are considered. In similar studies elsewhere, Krumholz (1944, 1951) reported recovering 86 percent of the marked fish from Twin Lake, a pothole lake seven acres in extent, in Oscoda County, Michigan, and 91 percent from a 1.4-acre pond on the farm of A. L. Lutz, near Evansville, Indiana. In both instances, all the recoverable fish were picked up for 10 days following the treatment with rotenone. Carlander and Lewis (1948) recovered about 60 percent of the marked fish from a small Iowa farm pond in five days, and Ball (1948) recovered 59 percent of the marked bluegills and 45 percent of the marked trout for a total of 52 percent in six days following the treatment of Ford Lake, Michigan, with rotenone. Although only seven days could be spent in picking up fish from White Oak Lake (the fish were too decomposed to be handled after that period), as many fish were recovered as by other workers in comparable situations. However, Ball, and Carlander and Lewis marked fish immediately prior to the treatment with rotenone whereas in the studies at White Oak Lake and the one by Krumholz in Michigan, the fish were marked as part of a population estimate as long as six weeks before the treatment. During such a long period of time many of the marked fish could have disappeared.

WEIGHTS OF FISH TISSUES

In order to set up a series of standard weights for each particular kind of tissue in the body of a fish, several individuals of each species of fish in White Oak Lake were completely dissected and the various component parts weighed. Each fish was dissected so that all the possible tissue belonging to each of the following categories was recovered and weighed: scales, skin, muscle, bone, fins, gill filaments, gill arches and rakers, eyes, stomach and pyloric caeca, intestine, heart, liver, gall bladder and contents, spleen, kidneys, head kidney or pronephros, central nervous system, abdominal fat, gonads, and contents of the digestive tract. For example, all the muscle tissue (flesh) in the entire body was separated from all other tissues and weighed as a unit, and each of the other tissues was handled in the same manner. So far as the bone was concerned, all the dermal elements of the skull, together with the lower jaw, vertebral spines, ribs, girdles, hypural elements, gill arches, and any other bones which were compact in their adult structure, were grouped together as compact bone, whereas the base of the skull and the bodies of the vertebrae were grouped together as cancellous bone.

For analysis and determination of the percentage composition of each tissue in the body, the tissues were then regrouped into (1) stable tissues, or those present in all individuals in relatively consistent amounts, and (2) variable tissues, or those which were present, if at all, in more or less variable amounts. Under the stable tissues, the scales, skin, muscle, bone, fins, gills, eyes, elements of the digestive tract, heart, liver, gall bladder and contents, spleen, kidneys, head kidney, and central nervous system were included. The variable tissues included the contents of the digestive tract, abdominal fat, and the gonads. In some individuals, the stomachs and intestines were fuller than in others, some fish contained more fat in the abdominal cavity than others, and the gonads in some fish were relatively much larger than in others inasmuch as the size of those organs changes from season to season in relation to the reproductive activities.

There are anatomical differences between the various species under consideration. Generally speaking, the anatomy of the bluegill is very similar to that of both species of crappies and the largemouth bass, and the different parts of the body are almost identical in structural formation. However, among the other four species the differences are much greater. In the carp and redhorse there is no stomach as such. Rather, the posterior end of the gullet opens directly into an enlarged anterior portion of the intestine. That enlargement gradually tapers off posteriorly into the intestine and there is no evidence of a pyloric valve as in the other species under consideration. Thus, the entire digestive tract in the carp and redhorse, from the posterior end of the gullet to the anus, was considered as the intestine. In the gizzard shad, the gizzard was included as part of the stomach. Among all of the centrarchids, the pyloric caeca were included with the stomach.

The anal and dorsal fins of all species were dissected out together with their bony attachments to the vertebral column, whereas only the exposed portions of the pectoral, pelvic, and caudal fins were included in the category of other fins.

During the dissecting process, some of the body fluids were lost. Part of those fluids were undoubtedly lost through evaporation and part through absorption by paper towels used in cleaning some tissues. However, it was possible in all cases to recover more than 90 percent of the live weight of the individual fish (Table 24).

In making calculations for the percentage of the total weight contributed by any particular organ or tissue, the combined weight of all the stable tissues recovered during dissection was considered as 100 percent. Then, the weight of each of the stable and variable tissues was figured as a percentage of that total weight of the recovered stable tissues.

A total of 43 individual fish referable to eight species were dissected as follows: 10 bluegills, 8 black crappies, 5 white crappies, 4 largemouth bass, 5 carp, 3 bullheads, 6 redhorse, and 1 gizzard shad. The average percentages of the total weight of the stable tissues, contributed by each of the individual weights of the stable and variable tissues, for the combined individual fish of each of the eight species, are listed in Table 24.

From these data it is evident that the weight of the leathery skin of the bullhead, where no scales are present, is relatively the same as that of the combined weights of the scales and skin in the other species. The scales of the carp and the redhorse were considerably heavier than those of the other fishes. The weight of the combined bony skeletons differs considerably from species to species, presumably because of differences in requirements for structural support in bodies of such diversified shapes. The eyes of the centrarchids, which feed largely by sight, are considerably

Table 24. Average percentages of total weight of stable tissues, contributed by each tissue dissected from individuals of eight species of fish from White Oak Lake, Roane County, Tennessee. The recovered weight indicates the percentage of the live weight recovered during dissection.

	Bluegill	Black crappie	White crappie	Largemouth bass	Carp	Bullhead	Redhorse	Gizzard shad
Stable tissues								
Scales	5.54	5.39	4.73	3.55	7.08	-	8.60	6.33
Skin	2.68	3.18	2.19	3.27	3.32	8.12	2.69	1.16
Muscle	67.96	65.52	68.10	65.64	61.97	61.01	68.08	70.38
Compact bone	5.20	7.22	5.78	7.05	5.10	8.53	4.65	3.67
Spongy bone	4.67	4.97	4.46	5.89	6.32	5.35	4.62	2.70
Dorsal fin	2.41	1.76	1.29	0.94	1.35	0.62	0.78	0.43
Anal fin	1.35	2.09	1.69	0.50	0.68	1.09	0.48	0.57
Other fins	1.93	2.12	2.20	1.27	2.28	1.81	2.28	1.56
Gill filaments	0.84	0.91	1.06	2.06	1.79	2.71	1.46	2.71
Gill arches	0.93	1.64	1.10	3.01	1.88	1.60	1.00	0.83
Eyes	2.03	1.96	2.02	2.30	1.12	0.17	1.11	1.16
Stomach	1.32	1.20	1.24	2.40	-	2.89	-	3.66
Intestine	0.55	0.39	0.43	0.45	1.25	1.76	0.99	1.07
Heart	0.16	0.09	0.14	0.08	0.24	0.12	0.13	0.21
Liver	1.19	1.03	1.17	0.84	3.65	2.25	2.00	1.90
Gall bladder	0.21	0.25	0.18	0.26	0.55	0.28	0.27	0.37
Spleen	0.11	0.10	0.06	0.08	0.13	0.05	0.11	0.14
Kidney	0.24	0.11	0.16	0.20	0.59	0.98	0.57	0.78
Head kidney	0.27	0.23	0.23	0.20	0.16	0.30	0.42	0.15
Central nervous system	0.45	0.33	0.34	0.28	0.72	0.36	0.37	0.22
Variable tissues								
Contents of digestive tract	0.46	0.49	0.56	0.98	1.14	0.23	1.06	0.74
Fat	0.45	0.42	0.19	1.24	0	0.27	0.40	0
Ovaries	4.21	1.50	1.55	0.91	6.13	0.24	0.72	-
Testes	0.22	0.44	0.52	0.06	2.22	0.34	1.03	2.98
Recovered weight	92.67	94.12	94.41	94.28	91.57	91.86	93.30	92.65

larger than those of the other species. The livers of the carp, bullheads, redhorse, and gizzard shad are much larger than those of the centrarchids, probably because of marked differences in diet.

Perhaps the most remarkable finding of this part of the study is the great similarity in the amounts of muscle tissue in the different species. Each of those kinds of fish is significantly different in shape from the others, yet the amount of muscle in each is approximately the same.

FOOD HABITS OF SOME FISHES

In conjunction with studies on seasonal changes in the accumulation of radiomaterials in the fishes of White Oak Lake, as described elsewhere in this report, it became essential to obtain information on the food habits of those animals. Inasmuch as presumably representative samples of two species of fish were being dissected each week for radioassay, the contents of the stomachs of those individuals were selected to supply the required data. Accordingly, the stomach contents of weekly samples of the three bluegills and three black crappies dissected during 1952 formed the basis for this study. As each fish was dissected, the relative amount of food in the stomach was visually estimated, the stomach contents removed, placed in a flask, weighed, and preserved in 70 percent alcohol. From January until May the stomach contents of all fish were kept in preservative, but after May the material was prepared for radioassay and counted. By assaying some of the samples for gross beta radioactivity, a comparison between the amounts of radioactivity in the stomach contents and that accumulated in the various tissues could be made.

The contents of each stomach was examined through a binocular dissecting microscope and the various organisms and other food material separated out and identified. After the identification of all material, the percentage of the total volume contributed by each kind of food in the sample was estimated. The variety and extremely small size of the various food materials made it impossible to obtain accurate weights for each item. However, in some instances where the entire contents of the stomach was made up of a single species of organism, the weight of that sample was available.

The food habits of the two species of fish under consideration were quite different. The black crappies fed primarily on those macroplankters which live as free-swimming organisms in the pelagic zone of the lake, whereas the bluegills were more omnivorous and generally foraged for food along the littoral zone.

Food of Black Crappies

The food habits of the black crappies in White Oak Lake were undoubtedly affected by the ecological conditions which prevailed during the study period. Under different conditions they might have utilized other foods even in the presence of large quantities of pelagic plankton. Only during periods when there was an apparent shortage of pelagic plankton did the crappies forage for other food along the littoral zone. Any decrease in the amount of pelagic forms in the stomachs examined usually occurred during the winter months. At that time, there was an increase in the types of food organisms common to the littoral zone.

The contents of the stomachs of 156 black crappies were examined during this study. Of those, 50 were empty. The remaining 106 stomachs ranged from about one-fifth full to full, and in most instances they were at least half full. The average weight of the contents recovered from those stomachs considered to be full was slightly more than half a gram (0.558 gram). None of those full stomachs appeared to be abnormally distended.

Most of the fish sampled were of comparable size, ranging from seven to nine inches in total length. It is reasonable to assume that the food requirements of all individuals were similar. Of the few fish that were outside that size group, none were so much larger or smaller that the food habits would have been noticeably different.

The variety of food materials found in the crappie stomachs is believed not to be as comprehensive as the following list implies. Rather, it is believed that some of the smaller organisms, which were only occasionally present in the stomachs, were picked up accidentally with other food items. The following list includes all organisms and animal materials found in the stomachs of black crappies in 1952:

Arachnida (pieces of spiders)

Arthropoda (pieces of grasshoppers)

Aquatic Coleoptera

- Gyrinidae (larva)
- Hydrophilidae (adult)

Cladocera

- *Alonella* (adult)
- *Chydorus* (adult)

Daphnia (adult)

Eurycercus (adult)

Moina (adult)

Psuedosida (adult)

Copepoda

Cyclops (adult)

Diaptomus (adult)

Diptera

Chaoborus (larva)

Tendipedidae (larva)

Culicinae (larva)

Ephemeroptera (unidentified larva)

Hemiptera

Corixa (adult)

Hymenoptera (small adult wasp)

Odonata

Anisoptera (dragon fly larva)

Zygoptera (damsel fly larva)

Rotifera (unidentified)

Trichoptera (unidentified larva)

Vertebrata (small fish)

In addition to the animal material listed above, there was frequently some vegetable matter present. Most of these materials are believed to have been ingested accidentally, such as phytoplankton which was taken in along with sought after zooplankters, and pieces of vascular plants or wood fibers which were either mistaken for organisms or eaten along with the organisms clinging to them. The following list of plant materials made up less than one percent of the contents of all stomachs examined:

Algae

Various filamentous types, chiefly Oscillatoria

Diatoms (very rare)

Volvox (present only when abundant enough to make the lake appear green)

Pieces of vascular plants and seeds

Detritus (pieces of decayed wood and dead leaves, sand and disentegrated pieces of rock)

The main preference for food exhibited by black crappies was for planktonic fauna as indicated by the data listed in Table 25. There, the percentages of the various food items which were found in the stomachs of black crappies each month are shown, together with the percentage composition of the diet for the entire year.

Of particular importance in the contents of the stomachs of the black crappies were the larvae of the phantom midge, Chaoborus. Those larvae exhibit a diurnal movement toward the water surface at night and apparently they were most vulnerable to predation by the crappies during that nocturnal migration. Frequently, the stomachs contained larvae in a stage just prior to pupation, indicating that the crappies caught them at or near the surface. Then, too, most of the fish with full stomachs were taken from the nets early in the morning.

Larval Chaoborus were found in the crappie stomachs every month in the year, and during five separate months those larvae constituted more

Table 25. Percentage of total volume made up by major groups of materials found in stomachs of black crappies each month during 1952, White Oak Lake, Roane County, Tennessee, together with the percentage composition of the diet for the entire year

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total
Number of fish	4	6	10	12	11	7	14	11	11	11	3	6	106
	Percentage of total monthly volume												
Terrestrial insects and spiders	-	0.9	-	-	-	-	0.7	-	2.7	-	-	-	0.4
Aquatic Coleoptera	-	-	-	4.5	-	0.4	-	-	-	-	-	-	0.4
Cladocera	-	-	-	17.3	40.4	0.3	-	2.0	1.2	6.4	14.7	0.2	6.9
Copepoda	49.0	36.7	29.6	0.3	0.2	-	-	0.4	0.5	3.9	30.3	10.3	13.4
Dipterous larvae <u>Chaoborus</u>	26.0	16.0	32.5	61.1	37.4	61.4	82.5	85.9	60.0	15.0	33.0	1.7	42.7
Dipterous larvae Tendipedidae	22.5	9.6	23.0	11.0	4.2	5.1	0.9	3.4	20.7	39.1	0.3	4.5	12.0
Aquatic Hemiptera <u>Corixa</u>	2.0	31.3	12.4	5.3	7.9	0.9	0.7	-	0.5	0.3	11.7	-	6.1
Other aquatic insect larvae	-	5.0	-	-	-	0.1	0.7	-	-	4.4	-	-	0.8
Fish remains	-	-	2.0	-	0.1	1.7	5.0	-	-	8.6	-	80.8	8.2
Digested animal material	-	-	-	-	6.7	21.9	9.1	7.8	14.1	22.3	10.0	2.5	7.9
Algae and plant material	0.5	0.5	-	-	3.1	0.3	0.2	0.3	0.3	-	-	-	0.4
Detritus and indigestible material	-	-	0.5	0.5	-	7.9	0.2	-	-	-	-	-	0.8

than 60 percent of the total volume. For the entire year, Chaoborus larvae made up about 43 percent of the total contents of the stomachs analyzed, and thus constituted the major item in the diet of the black crappies in White Oak Lake.

The copepods were grouped together because the fish showed no preference for any particular species. This group of plankters was the second most abundant group in the contents of the stomachs examined. The cladocerans or water fleas were grouped together in the same way as the Copepoda, and made up about 7 percent of the diet. These two groups, when combined, constituted more than 20 percent of the total annual food found in the stomachs of the black crappies.

Midge larvae of the family Tendipedidae made up 12 percent of the total annual diet of the black crappies. These larval forms are numerous in White Oak Lake, but are usually confined to the littoral zone. However, they are found on almost any type of submerged material where they construct protective cases around themselves. Inasmuch as they are almost constantly squirming, that motion apparently attracted some fish, but when they are about to pupate, the larvae swim to the surface, and it is at this stage of development that they are most frequently found in the crappie stomachs.

Small fish were eaten only occasionally, and those were probably caught while the crappies were foraging along the littoral zone. Other organisms from the littoral zone which were eaten by the crappies were the aquatic hemipteran, Corixa, and the larval forms of aquatic Coleoptera. Corixa are quite numerous in the littoral zone, and made up approximately 6 percent of the annual diet during 1952.

Food of Bluegills

One hundred of the 156 stomachs of bluegills examined contained identifiable food materials. The stomachs ranged from one-sixth full to full, and only a few were less than half full. The average weight of the contents of those stomachs considered to be full was 0.383 gram, approximately two-thirds that of the black crappies. From all appearances, none of the full bluegill stomachs was abnormally distended. The total lengths of the bluegills dissected ranged from about five to about seven inches.

The food items taken from the stomachs of bluegills, as listed below, gives the impression that they will eat practically anything. The general scarcity of food organisms in much of the littoral zone, where the water is deep enough to be negotiated by fish other than fingerlings, indicates that many of the bluegills, particularly the larger individuals, may have been on a near starvation diet. The list of food items found is as follows:

Arachnida (pieces of spiders, water mites)

Hymenoptera (small ants, bees, wasps)

Diptera

  Black flies (terrestrial)

  Chaoborus (adult and larva)

  Tendipes (adult and larva)

Lepidoptera (butterfly, pieces of moths, caterpillars)

Coleoptera (terrestrial - small beetles, June beetles)

  (aquatic - Haliplidae - adult, Hydrophilidae - adult)

Hemiptera (terrestrial - lace-bug)

  (aquatic - *Corixa*)

Cladocera

Alonella

Chydorus

Daphnia

Copepoda

Cyclops

Odonata

Anisoptera (dragon fly larva)

Zygoptera (damsel fly larva)

Ephemeroptera (unidentified larva)

Trichoptera (unidentified larva)

Pulmonata

Gyraulus

Vertebrata (small fish, eggs)

Bryozoa (statoblasts from *Pectinatella*)

Homogeneous mass of partially digested but unidentifiable animal material

Algae (filamentous)

Spirogyra

Oscillatoria

Volvox (accidental to diet--see section on black crappies)

Euglena (encysted stages)

Vascular plants (pieces of stems, leaves, and some seeds)

Bryophytes (pieces of moss)

Detritus (pieces of wood, sand, disintegrated rock fragments, and feathers)

There was actually very little preference for any particular ki food shown by the bluegills, as indicated by the data in Table 26. Th high percentage of plant remains and algae in the stomachs, which made about 43 percent of the annual total, probably results from those item being eaten inadvertently. Those forms of vegetation occur in consider abundance along the littoral zone where the bluegills do most of their feeding. The stomachs contained a large variety of organisms and it wa only during the hottest summer months that the pelagic Chaoborus larvae made up an important part of the diet. At that time, those organisms we very abundant in the deep water and the relatively high temperatures of water along the shore probably forced the bluegills to seek the cooler water near the middle of the lake. Larval Tendipes were numerous along th shore of the lake and were frequently eaten, making up more than 11 percen of the total annual diet.

The variety of food eaten by the bluegills in White Oak Lake indica that they were probably searching for food constantly, and, by foraging ne the shoreline they encountered many terrestrial insects which fell into the water. Portions of those insects were found in the bluegill stomachs throughout the year and apparently provided an important segment of the annual diet.

Radioactivity in Stomach Contents

The stomach contents were prepared for radioassay and counted in the same manner as the other animal tissues as described elsewhere in this report. The amount of radioactivity in the contents of the black crappie stomachs ranged from 105 to 1,800 counts per minute per gram, whereas those

Table 26. Percentage of total volume made up by major groups of materials found in stomachs of bluegills each month during 195[illegible], White Oak Lake, Roane County, Tennessee, together with the percentage composition of the diet for the entire year

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total
Number of fish	3	5	10	12	8	10	13	11	12	8	2	6	100
Water mites	-	-	3.0	1.8	-	-	-	-	-	-	-	-	0.4
Terrestrial insects and spiders	1.7	8.0	10.3	12.1	23.5	1.1	0.2	2.2	0.9	22.6	-	1.8	7.0
Aquatic Coleoptera	-	-	5.5	2.2	-	7.0	0.2	-	-	0.1	12.5	1.0	2.4
Cladocera	-	-	0.1	0.2	14.2	-	-	0.3	0.3	-	-	0.8	1.3
Copepoda	-	-	0.2	0.2	0.1	-	-	-	0.8	-	-	-	0.5
Chaoborus (larvae)	-	-	-	4.5	12.5	22.8	32.0	27.9	9.8	-	-	-	9.1
Tendipedidae (larvae)	3.0	23.4	37.2	14.2	23.6	6.2	1.1	2.3	6.3	8.8	10.0	2.2	11.5
Corixa	-	2.0	10.8	2.5	1.2	-	-	-	0.2	-	-	-	1.4
Other aquatic insect larvae	0.7	3.0	0.1	0.7	=	0.1	-	6.0	-	-	1.5	-	1.0
Fish remains	-	0.4	0.1	3.1	1.1	0.6	7.3	0.6	-	6.4	15.0	-	2.9
Digested animal material	-	6.0	3.0	19.1	6.8	21.0	7.6	32.5	12.8	8.1	11.0	48.7	14.7
Filamentous algae	37.6	17.2	-	16.9	4.6	23.1	16.0	7.6	38.2	33.8	48.5	35.0	23.2
Vascular plant materials	48.3	37.0	28.4	19.2	3.1	17.1	27.3	18.7	14.2	12.9	-	8.8	19.6
Detritus and indigestible material	8.7	3.0	1.3	3.2	9.1	1.0	8.2	2.0	17.1	7.4	1.5	1.7	5.2

of the bluegills ranged from 250 to 14,350 counts per minute per gram. The average for the contents of the full crappie stomachs was 960 counts per minute per gram, whereas that for the full bluegill stomachs was 1,250. The differences in the amount of radiomaterials in the stomach contents of the two species of fish is probably traceable to the greater abundance of filamentous algae eaten by the bluegills. Samples of *Oscillatoria* and *Spirogyra* taken from the lake contained as much as 13,000 and 17,000 counts per minute per gram respectively.

Of the bluegill stomachs that contained rather large amounts of radioactivity, four contained fairly large amounts of filamentous algae as follows: (1) 40 percent algae - 5,340 counts per minute per gram, (2) 90 percent algae - 7,170 counts per minute per gram, (3) 95 percent algae - 5,400 counts per minute per gram, and (4) 70 percent algae - 4,350 counts per minute per gram. However, the stomach contents that contained the greatest amount of radioactivity contained no algae whatsoever, but rather a group of small sound objects somewhat similar to cladoceran eggs. Unfortunately, no parent animals were present for identification.

Samples of *Tendipes* collected from the lake ranged in radioactive content from 150 to 2,770 counts per minute per gram, whereas those of *Chaoborus* ranged from 540 to 1,340 counts per minute per gram.

None of the samples of stomach contents were analyzed radiochemically. However, analyses of samples of *Chaoborus*, *Tendipes*, and a mixed sample of *Daphnia* and *Diaptomus* were shown to contain several radioelements in the following percentages:

	Phosphorus	Rare earths	Strontium	Cesium
Chaoborus (July 1952)	95.0	2.0	0.5	1.1
Tendipes (June 1952)	50.0	6.0	6.6	3.3
Mixed Cladocera (June 1952)	55.4	25.7	12.0	4.6

Among the filamentous algae sample of _Oscillatoria_ and _Spirogyra_ yielded the following results on radiochemical analysis:

	Phosphorus	Rare earths	Strontium	Cesium
Oscillatoria	9.6	32.4	3.4	9.8
Spirogyra	13.6	11.8	7.3	1.0
Spirogyra	42.3	38.3	22.0	-

From these data it is apparent that the majority of the zooplankters analyzed had concentrated radiophosphorus more than any other nuclide, whereas among the filamentous algae, the rare earths were assimilated in amounts almost equal to the radiophosphorus. In addition, there was an accumulation of definite amounts of radiostrontium in all organisms. In another section of this study, it is pointed out that the bony structures of the fish accumulated various amounts of radiomaterials depending on the metabolism of the animal as correlated with temperature changes during the different seasons of the year. Yet, in that concentration of radiomaterials, it has been shown that approximately 85 percent of the radioactivity in the bones was emitted by strontium and 10 percent by phosphorus irrespective of the time of year.

Furthermore, the concentration of radiomaterials in the stomach contents of the two species of fish under consideration, indicates that the bluegills contained an average of about 25 percent more radiomaterials than the black crappies. However, as will be shown later in detail, the black crappies accumulated about 50 percent more radiomaterials in the hard parts of the body than did the bluegills. Among the soft tissues the bluegills concentrated more radiomaterials than the crappies.

Thus, it appears that one or more of several things may occur during the assimilation of radiomaterials by fishes: (1) the radiophosphorus in the food organisms may not be in a form that is physiologically acceptable to the fish; (2) the biological half life of the phosphorus may be so short that large amounts do not accumulate, this, however, seems unlikely inasmuch as large amounts do accumulate in the muscle tissue of waterfowl; (3) the physiological demand for strontium by the fish is so great that all that is available in the food materials is incorporated in the fish tissues; (4) the strontium, or some other element that is already present in the fish tissue, tends to inhibit the deposition of large amounts of phosphorus; (5) the amount of radiophosphorus accumulated is near the level of saturation for those tissues; (6) the seasonal variation in the accumulation of radiomaterials in the fish may be controlled to a certain extent by the differences in abundance of preferred food materials available during the different seasons of the year; and (7) the physiological requirements for various elements differ markedly, even between closely related species of fishes.

A consideration of these and other factors, either singly or in combination, points up the fact that there is much to be learned about the methods and rates of accumulation of radiomaterials in animals under natural conditions. In addition, very little is known about the physiological requirements of these animals for the so-called trace elements.

ACCUMULATION OF RADIOMATERIALS BY FISHES

One of the primary functions of the Ecological Survey of White Oak Creek was the determination of the amounts and kinds of radioactive substances accumulated by the fish of White Oak Lake during their normal life processes. Accordingly, a program of sampling different tissues of individual fish of the various species present in the lake was set up to determine which tissues concentrated the greatest amounts of such materials, and which radioelements they concentrated.

Materials and Methods

All fishes used in this study were caught in hoopnets set in the same location at Net Station 4 (Figure 1). Whenever the net was lifted, the fish to be used for radioassay were selected so that individuals of the different sizes of the several species under consideration would be sampled. The fish were taken from the net, placed in a bucket of lake water, and taken to the laboratory.

Scanning. While still alive, selected individual fish were scanned for gross beta radioactivity with a probe constructed especially for that purpose. That probe, developed by J. M. Garner, Jr., of the Waste Disposal Research Section, had an outside diameter of three-eighths inch and could readily be inserted into the mouths and gullets of bluegills and other centrarchids of a greater length than six inches. The wall of the probe was of stainless steel having a thickness of 30 milligrams per square centimeter to allow for the penetration of beta particles. The sensitive portion of the probe was located about three-eighths inch from the tip so that when it was inserted into a fish's stomach the radioactivity of the surrounding tissues, including the contents of the stomach, could be detected. Each fish was scanned for a period of five minutes while totally submersed in water, and then a background reading of five minutes was recorded with the probe imersed in the pail of water from which the fish had been removed.

Dissection. Immediately following the scanning, if the particular fish had been scanned, each animal was removed from the pail, killed, dissected, and samples of the various tissues taken for radioassay. As the samples were taken, they were placed in glass-stoppered Erlenmeyer flasks of 25 milliliter capacity which had previously been weighed. The stopper was then inserted so that drying out of the tissues would be held to a minimum. Whenever possible, a sample of at least 0.5 gram in weight was used. Samples of tissues were taken as follows:

Scales. The fish was wiped clean with a fresh paper towel and the scales, together with the attached epidermal tissue, removed from one side of the body. No effort was made to clean each individual scale. If the fish was relatively large, a sample of scales weighing more than a gram was removed for assay.

Skin. After all the scales had been removed from one side of the body, the skin of that entire side, including the dermis and the remaining epidermis, was peeled away from the flesh. It was then scraped clean of all attached tissues.

Muscle. The sample of flesh was usually taken from the dorsolateral area immediately behind the head. That area is free of bones and easily removed. The sample of muscle usually weighed at least a gram.

Bone. For purposes of this study, the bones of the fish were separated into two categories: compact bone, and cancellous or spongy bone. The samples of compact bone usually consisted of both cleithra, about ten ribs, and some bones of the opercular series. These bones were cleaned of flesh and wiped off with facial tissue. The samples of cancellous bone usually included the bodies of all the vertebrae from which the processes and attached flesh had been removed.

Fins. For purposes of this study, the fins were separated into three categories, dorsal fin and attachments, anal fin and attachments, and the combined pectoral, pelvic, and caudal fins. The entire dorsal fin, both the spiny-rayed and soft-rayed portions, together with the bones for attachment to the vertebral column, were scraped clean of attached muscle and wiped with facial tissue. No attempt was made to remove the skin that covered the exposed part of the fin. The anal fin was removed in much the same manner as the dorsal fin and the entire appendage used in the sample. Preliminary assay indicated that the external parts of the pectoral, pelvic, and caudal fins accumulated approximately the same amounts of radiomaterials. Accordingly, these fins were excised at their bases, wiped clean of any attached scales and moisture, and only the exposed portions used as the sample.

Gills. The gill structures were separated into two categories in this study, the gill filaments, and the gill arches together with the covering and rankers. In the sample for gill filaments, all the filaments were recovered and blotted free of excess moisture. In the sample for gill arches and rakers, all arches and rakers from both sides were removed and blotted free of excess moisture. None of the median bones were included in the samples.

Eyes. Both entire eyeballs, exclusive of the attached muscles and nerves.

Stomach and pyloric caeca. The stomach was excised at its anterior and posterior ends and all contents removed. The attached caeca were left intact together with their contents.

Intestine. The entire intestine, from the posterior end of the stomach to the anus was excised and separated from its contents and any attached fat.

Heart. The entire heart, including the conus arteriosus and the sinus venosus, free of any blood.

Liver. The entire liver, exclusive of the gall bladder.

Gall bladder and contents. The gall bladder and contents, free from any liver tissue.

Spleen. The entire spleen.

Kidney. The entire kidneys of both sides including the ducts.

Head kidney or pronephros. The entire head kidney, lymphoid in structure.

Central nervous system. The entire brain and spinal cord, exclusive of the protective sheaths.

Gonads. Both testes or both ovaries were included in the sample whenever feasible. In instances where the ovaries were too large to be included, a sample more than one gram in weight was used.

Contents of the digestive tract. Early in the study the contents of the stomach were combined with those of the intestine. After the first week in May 1952, the contents of the stomach and the contents of the intestine were assayed separately.

Fat. In those fish where there was enough abdominal fat to afford an adequate sample, that sample was taken. Radioassay of those samples indicated that little or no radioactivity was accumulated by that tissue and after May 1, 1952, it was no longer sampled.

Preparation of tissues for radioassay. The method of preparation, a modification of the nitric acid wet digestion method, was developed in collaboration with A. H. Emmons of the Waste Disposal Research Section and has been published in the open literature (Krumholz and Emmons, 1953).

Counting. All counting was done in the counting room of the Health Physics Division under the supervision of Juanita C. Anderson. The counts were made on the second shelf of end-window Geiger-Mueller scalers at a geometry of approximately 10 percent depending on the particular counter used. Each duplicate of each sample was counted for 20 minutes. Three readings for background were taken on each machine for 20 minutes three times each day. The background for each sample count was obtained by scaling up or down between the two background readings on either side of the counts. Any duplicates of samples which differed from each other by more than 10 percent of the net count were recounted, or, if necessary, new duplicates were pipetted and counted.

Radiochemical analysis. Radiochemical analyses on individual samples were performed by either A. H. Emmons or Bernd Kahn of the Waste Disposal Research Section. The more extensive work on radiochemical analysis was done in the laboratories of the Analytical Chemistry Division, Oak Ridge National Laboratory, under the supervision of C. L. Burros. Inasmuch as the entire sample prepared for radioassay was not used in counting, the remaining portion of the solution of each tissue from each of the two species of fish was composited with the remaining portions of similar solutions. For example, the unused portions of all samples of bluegill scales were placed in a single bottle, accumulated for a period of three or four months, and then analyzed. There was no need for immediate analysis following the radioassay because preliminary analyses had indicated that well over 90 percent of the radioactivity present was emitted by radionuclides with very long physical half lives. Furthermore, it was found through preliminary analyses that more than 90 percent of the radiomaterials present in the fish were radioactive isotopes of strontium, rare earths, cesium, and ruthenium. Consequently, analyses were made for only those elements by Mr. Burros' group.

Seasonal Changes in the Accumulation of Radiomaterials by Fishes

Preliminary results of radioassay of fish taken from White Oak Lake in the summer of 1951 revealed that those fish had accumulated considerably more radioactivity than those taken during the previous winter. In the light of these preliminary findings, it was decided to make a year-round survey of the accumulation of radioactive materials in the fish of White Oak Lake. Accordingly, three black crappies and three bluegills were dissected each week from September 1951 until January 1953. Those two species were selected for study because they were abundant in the lake and were easily caught in hoopnets. All of the dissection was performed by W. T. Miller and L. A. Krumholz in order to minimize the discrepancies that might arise from individual techniques. The fish were prepared for radioassay and counted according to the techniques outlined earlier.

The data for the amounts of gross beta radioactivity in the samples of tissues from the individual fish are listed for the black crappies and bluegills in Tables 1 and 2 respectively of the Appendix to this section of the report. Those data for the individual fish were grouped by weeks and averaged, and the weekly averages then treated with a moving average of five in order to smooth out the curves to show any seasonal changes in the accumulation of radiomaterials that took place.

The amounts of radioactivity accumulated in five different tissues from black crappies, as indicated by a moving average of five applied to the weekly averages, are presented graphically in Figure 6, whereas similar curves for the bluegill tissues are shown in Figure 7. From these figures it is obvious that there are marked seasonal differences in the amounts of

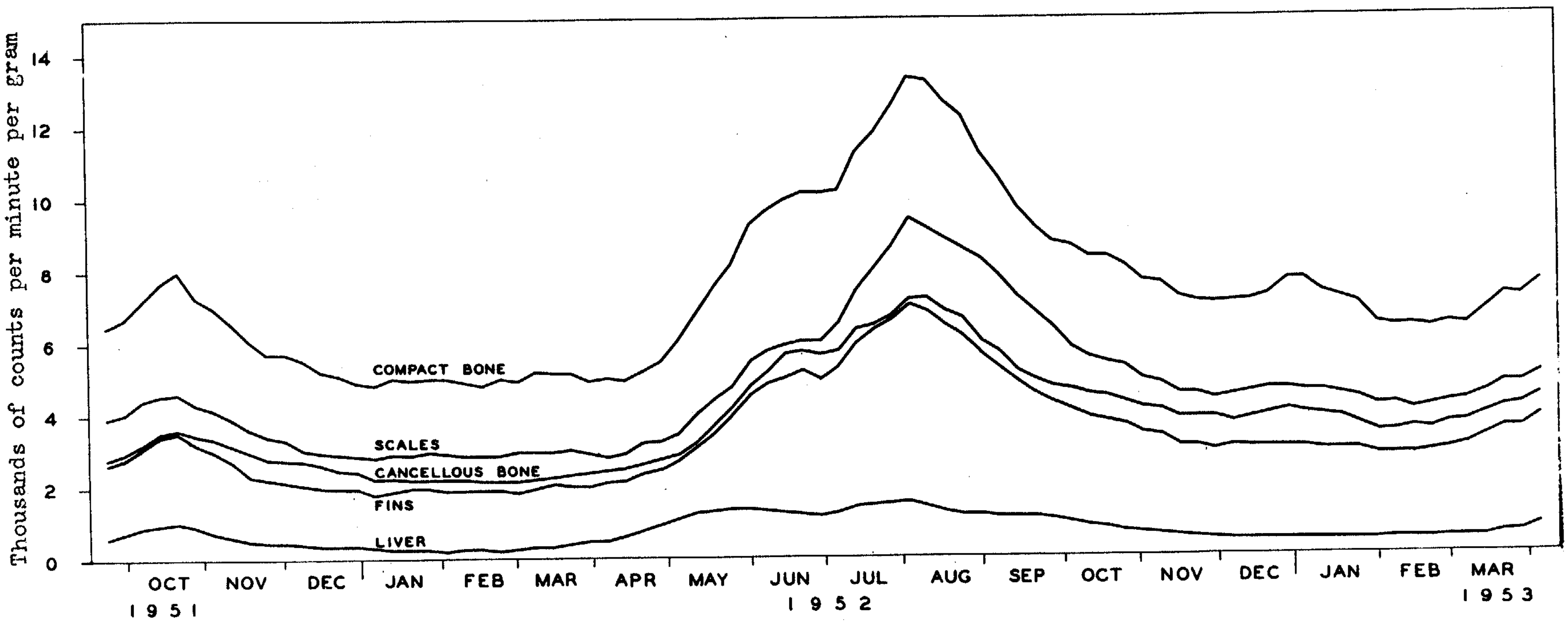


Figure 6. Amounts of radioactivity accumulated in each of five different tissues from black crappies taken from White Oak Lake over an eighteen-month period, 1951-1953

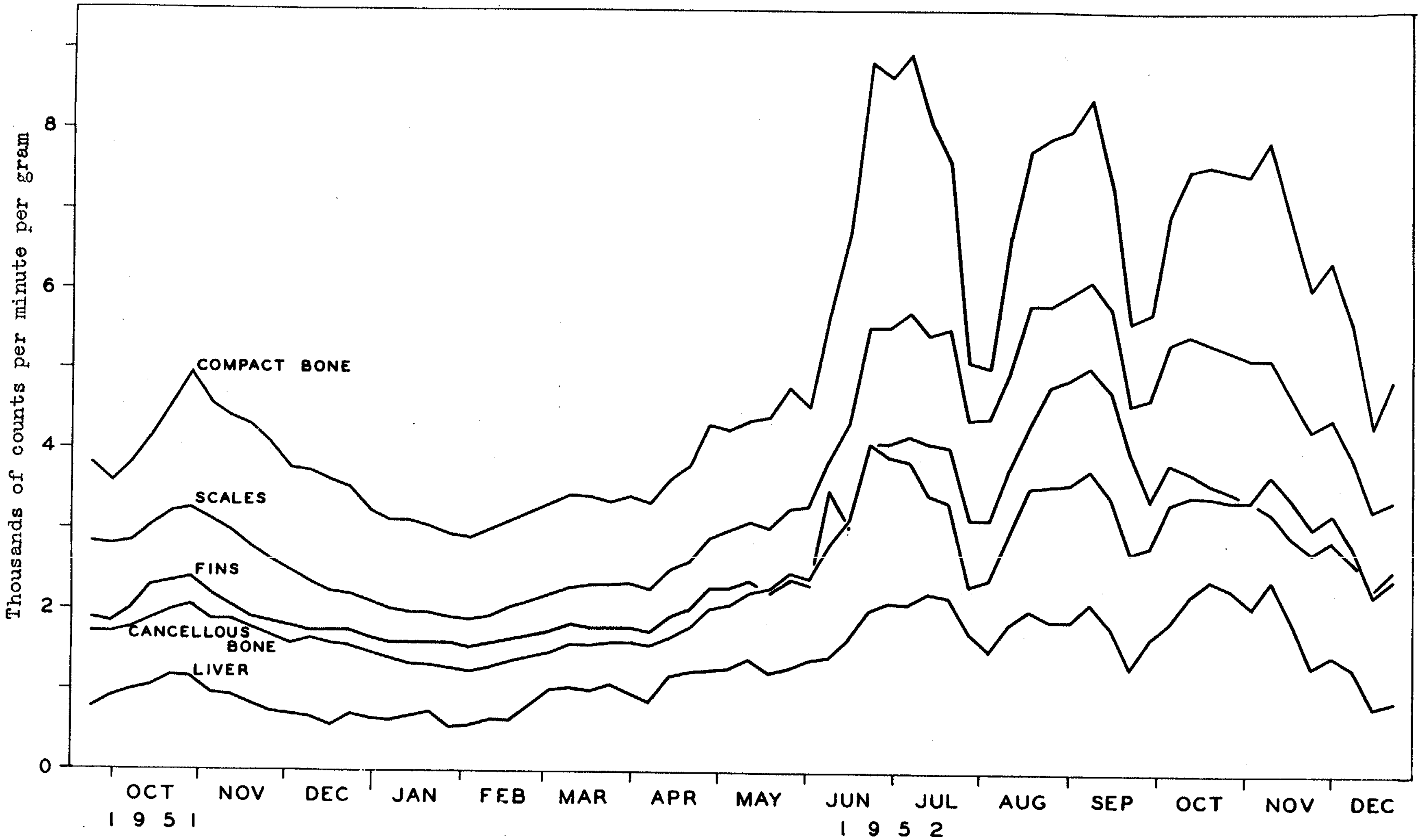


Figure 7. Amounts of radioactivity accumulated in each of five different tissues from bluegills taken from White Oak Lake over a fifteen-month period, 1951-1952

radiomaterials accumulated by both the soft and hard tissues of both species of fish. Furthermore, it is obvious that the same seasonal changes are reflected in all tissues represented in the figures. These particular tissues were chosen for demonstration in the figures because of their relatively high concentration of radiomaterials. The other tissues assayed showed much the same fluctuations although the tissues had not accumulated such large amounts of radioactivity.

The curves for the black crappies are considerably smoother than those for the bluegills. The most plausible explanation for the relative smoothness of the curves for black crappie tissues, and the lack of that quality in those for the bluegills, seems to stem from the differences in the diets of the two species in White Oak Lake as indicated elsewhere in this report. In essence, the bulk of the diet of the crappies consisted of larval forms of various midges along with microcrustaceans, whereas the diet of the bluegills was tremendously varied. Thus, it is believed that the sample of three crappies per week was adequate for determining the trends of accumulation of radiomaterials on a year-round basis, whereas such a sample of bluegills was inadequate. Perhaps a sample of 10 bluegills per week would have yielded satisfactory results.

It is well known that in all poikilothermous animals the temperature of the body is largely controlled by the temperature of the environment. Also, there is a direct relationship between the metabolic rate and temperature in such animals; as the temperature increases the rate of metabolism increases and vice versa. Certainly, the increase in the concentration in radiomaterials, as indicated in Figures 6 and 7, was closely related to the rise in water temperature during the spring of the year, as shown by the data in Tables 25 and 26 of the Limnology Section of this report. Based on those data on water temperatures, it appears that the spring increase in the accumulation of radiomaterials by the fish began when the water reached a temperature of about 55° F. When that temperature was reached in the environment, the fish began to accumulate radiomaterials very rapidly, and by mid-June had more than doubled the amounts carried during the winter months. The midsummer peaks in water temperatures and accumulated radio-elements in the fishes were reached simultaneously about August 1, 1952. At that time the water temperature reached a high of approximately 80° F., which was less than twice the average winter temperature, whereas the fish had very nearly tripled the amounts of radiomaterials maintained over the winter. From that point on, the amounts of radiomaterials in the fish samples fell off rather rapidly, while the water temperature decreased gradually over the next two or three months and did not drop below 55° F. until sometime in October. If the accumulation of radiomaterials by the fish of White Oak Lake is a direct result of their metabolic processes, and no doubt it is, the sharp decrease in accumulation during August and September, when the temperature of the environment remained relatively high, is a good indication that the metabolic processes underwent a marked change during that period. The most plausible explanation appears to be that the fish probably entered a period of aestivation.

The minimum, average, and maximum amounts of gross beta radioactivity, in counts per minute per gram of tissue, wet weight, for six selected tissues from the black crappies and bluegills assayed during January, February, and March 1952, and January 1953, as compared with similar data for June, July, and August 1952, are listed in Tables 27 and 28 respectively.

Table 27. Minimum, average, and maximum amounts of radioactivity, in counts per minute per gram, fresh weight, accumulated in samples of selected tissues of black crappies, for three different three-month periods, White Oak Lake, Roane County, Tennessee

Tissue	January-March, 1952			June-August, 1952			January 1953		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Compact bone	2,650	5,000	6,750	5,550	11,500	19,600	4,800	6,650	10,600
Scales	2,200	3,000	4,950	4,050	7,500	12,900	2,600	4,300	5,500
Vertebral bodies	1,300	2,200	3,150	2,450	6,350	10,650	2,250	3,650	5,250
All fins	1,300	1,950	2,550	2,550	5,900	9,900	1,950	2,900	3,900
Liver	35	270	620	670	1,350	1,870	110	410	860
Muscle	16	35	50	110	240	450	7	25	50

Table 28. Minimum, average, and maximum amounts of radioactivity, in counts per minute per gram, fresh weight, accumulated in samples of selected tissues of bluegills, for two different three-month periods and one one-month period, White Oak Lake, Roane County, Tennessee

Tissue	January-March, 1952			June-August, 1952			January 1953		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Compact bone	2,050	3,250	4,900	2,100	7,150	30,400	3,700	5,750	7,500
Scales	950	2,100	2,850	1,600	5,000	16,800	3,100	3,550	4,900
Vertebral bodies	1,000	1,400	1,950	1,100	3,250	13,400	1,950	2,900	3,750
All fins	1,150	1,650	2,250	1,150	3,650	13,600	1,850	2,950	4,750
Liver	180	810	3,700	550	1,850	5,150	300	1,100	2,150
Muscle	10	55	150	65	220	1,050	20	70	170

From these data it is obvious that there was more than twice as much radioactivity in all tissues during the summer than during the preceding winter. It is also obvious that there were significantly greater amounts of radiomaterials in the fish during the second winter than during the first. Data compiled by the Area Monitoring Group of the Applied Health Physics Section show that during January and February 1953 there was about a five-fold increase in the amount of radioactivity that passed over the dam of White Oak Lake over that spilled in the same period in 1952.

In addition, it is obvious from a perusal of the data in Tables 27 and 28 that the crappies accumulated considerably greater amounts of radiomaterials in the hard tissues than the bluegills, whereas among the soft tissues the reverse was generally true. These differences are shown graphically for two selected tissues in Figure 8. The reasons for such differences are not obvious. It may be that the differences in diet were a contributing factor. Also, it may be that the physiological requirements for the elements represented are different for the two species involved. If such differences in physiological demands for certain elements are so great between two species so closely related as the black crappie and the bluegill, any prediction of the relative amounts of radiomaterials that might be accumulated by unrelated species of fish would be pure speculation.

The average amount of radioactivity in the water of White Oak Lake, as determined by the Area Monitoring Group of the Applied Health Physics Section, was 4.5 counts per minute per milliliter during July 1952. Radiochemical analysis of the July sample by that same group indicated that about 24 percent of the radioactivity was emitted by radiostrontium. The maximum amount of radioactivity detected in the bones of black crappies

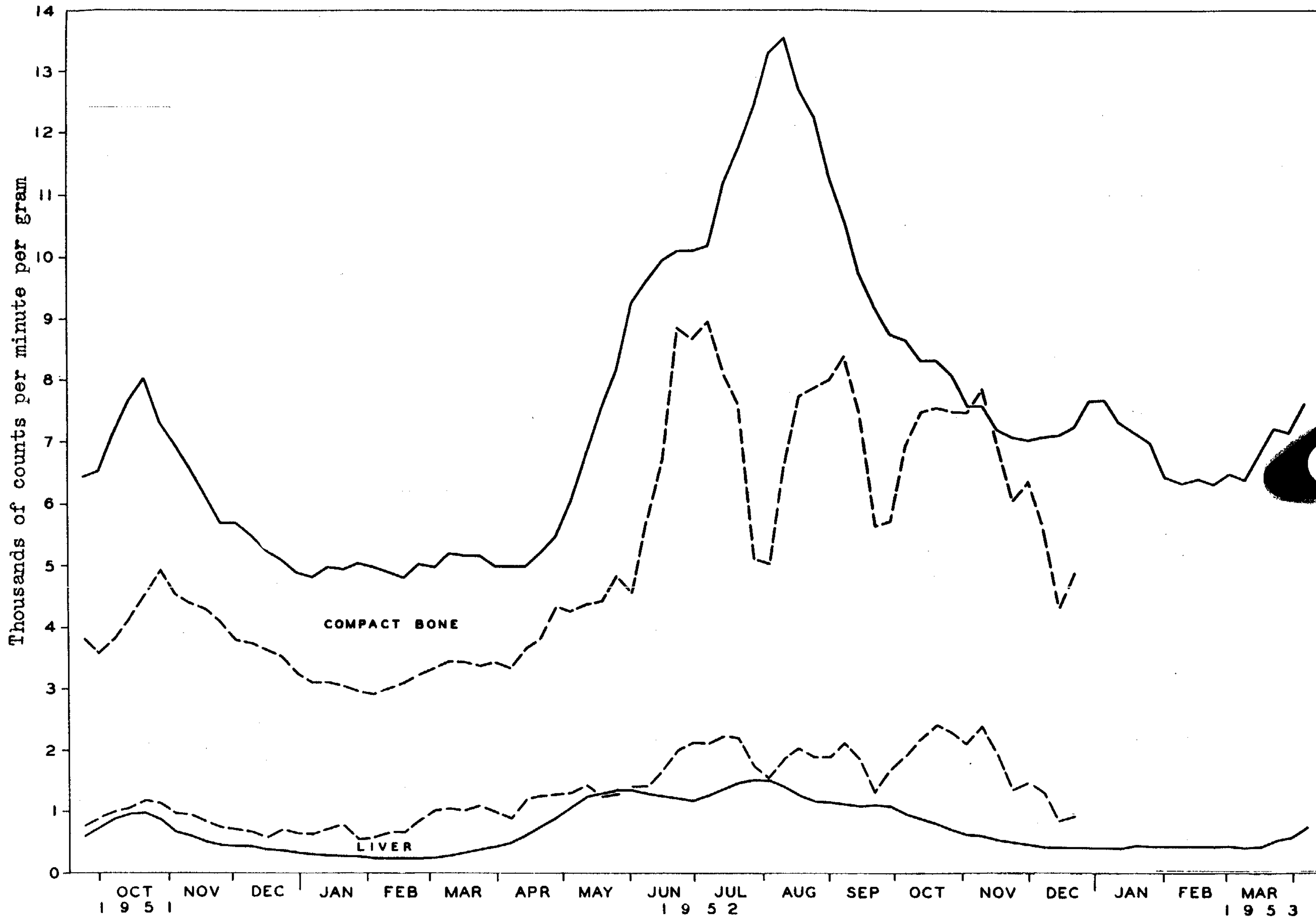


Figure 8. Comparison of amounts of radioactivity accumulated in each of two tissues from black crappies (solid lines) and bluegills (broken lines) from White Oak Lake during an eighteen-month period, 1951-1953

(July 29, 1952) was approximately 19,000 counts per minute per gram. From these data it is apparent that there is a concentration factor of nearly 20,000 to 1 from the lake water to that tissue. Similar data for the bluegills (July 8, 1952) show a concentration factor of more than 30,000 to 1 for selected individuals.

Radiochemical Analysis of Fish Tissues

Radiochemical analyses of the composite samples of the various tissues of the black crappies and bluegills revealed the presence of the following radionuclides that had been accumulated: strontium 89, strontium 90 and its yttrium 90 daughter, cesium 137, cerium 144 - praseodymium 144 and other rare earths, ruthenium 106, cobalt 60, phosphorus 32, iodine 131, zirconium 95, and niobium 95. However, each of those radioelements was selectively concentrated by separate tissues; the hard tissues concentrated primarily strontium and phosphorus, whereas the soft tissues generally concentrated cesium in greater amounts than any other radionuclide. Among the black crappies, representative hard tissues (compact bone, cancellous bone, scales, and dorsal fin) contained consistently the same percentages of radiomaterials at all seasons of the year, irrespective of the actual amounts of such materials accumulated. Approximately 85 percent of all the radioactivity in each of those tissues was emitted by strontium 89 and strontium 90 and its yttrium 90 daughter, and about 10 percent by phosphorus 32. The remaining 5 percent consisted of small amounts of the various elements mentioned above. Among the same tissues in the bluegills, much the same pattern of accumulation was found. There, about 82 percent of the radioactivity was emitted by radiostrontium and its daughter products, about 10 percent by radiophosphorus, and the remainder of various amounts of the different elements listed above.

Among the soft tissues of both species of fish, the main source of radioactivity was from the cesium 137 accumulated in them (Knobf, 1951), together with smaller amounts of ruthenium 106, cerium 144 - praseodymium 144, niobium 95, and zirconium 95. The amount of radiocesium varied from about 50 to 90 percent with an average of approximately 75 percent. The greatest amount of ruthenium 106 detected, comprised about 10 percent of the total. None of the other elements were ever found to have contributed more than about 3 percent with the single exception of cobalt 60. In one instance, the livers of several bluegills were found to be highly radioactive (more than 8,000 counts per minute per gram). Radiochemical analysis showed that very nearly all of that radioactivity was emitted by cobalt 60.

ACCUMULATION OF RADIOMATERIALS BY WATERFOWL

During their annual migration, relatively large numbers of migratory waterfowl frequent White Oak Lake as a resting place as indicated elsewhere in this report. Some birds apparently stop over for only a few days whereas others remain for many weeks and may winter there as indicated in another section of this report.

The feeding habits of these waterfowl, coupled with the ready availability of long-lived radiomaterials in the bottom muds and algae of the lake, make it seem likely that some birds might accumulate radionuclides and carry them elsewhere. There is also the possibility that such birds might constitute a hazard if eaten by a hunter or his family. Thus, as part of the program to investigate the possible effects of radioactive effluents on the various animals using White Oak Lake, a preliminary program on the accumulation of radiomaterials by migratory waterfowl was undertaken.

Materials and Methods

The carcasses of 18 American coots (*Fulica americana*), 13 common mallards (*Anas p. platyrhynchos*), 8 black ducks (*Anas rubripes*), 8 wood ducks (*Aix sponsa*), 2 gadwalls (*Chaulelasmus streperus*), and 1 green-winged teal (*Nettion carolinense*) were dissected and the various tissues sampled. All dissection was done by W. T. Miller and L. A. Krumholz. Samples of the following tissues were taken from most of the birds: eyes, feathers, bill, brain, skin, muscle, heart, thyroid, trachea, lung, pancreas, spleen, liver, gizzard, intestine, caeca, kidney, adrenals, long bone, gonads, and the contents of the various portions of the digestive tract. However, in the case of 1 coot only 12 tissues were sampled, and only 5 tissues were sampled from each of 6 of the wood ducks. Those 6 wood ducks had been killed when attacked by predators in one of the duck traps.

All of the samples were prepared for radioassay by the method described by Krumholz and Emmons (1953). Samples of the contents of the gizzard usually contained fine sand, gravel, and heavy clay materials. After the soluble material in those samples had been dissolved in nitric acid, the solution was decanted off into another container. The insoluble material was then washed several times with nitric acid, followed by washings of distilled water, and all of the supernatant liquids added to the original sample of soluble material, which was then treated as any other sample being prepared for radioassay. The solids (sand, gravel, and clay) were then dried and weighed and that weight subtracted from the weight of the original sample. So far as could be determined, the solids removed from the samples of gizzard contents did not contain any radiomaterials after the above treatment.

The samples were then diluted with distilled water to a known volume, pipetted, and counted as outlined in an earlier section. All measurements of radioactivity are listed in counts per minute per gram, fresh weight, at approximately 10 percent geometry depending on the particular counter used.

Aluminum absorption curves and decay curves were prepared for a selected number of samples in an effort to establish the identity of the radioelements encountered. Radiochemical analyses were made of muscle samples and the contents of the caeca and intestines of one coot and one gadwall.

Unfortunately, the exact time of arrival and the length of time spent at White Oak Lake by any of the birds are unknown. However, the coots apparently had taken up winter residence at the lake and remained there most of the time. Many of the ducks, on the other hand, left the lake almost daily in their search for food. One of the gadwalls (Gadwall #2) had become crippled in an unknown manner and, being unable to leave the lake, was forced to remain there and feed. Thus, it is impossible to determine the rate of accumulation of radiomaterials in any of the birds studied.

The data for the amounts of gross beta radioactivity detected in each sample of tissue from each of the waterfowl assayed are listed in the appendix to this section as follows: American coots in Table 3, mallards in Table 4, black ducks in Table 5, wood ducks in Table 6, and the gadwalls and green-winged teal together in Table 7.

Of the birds sampled, the various tissues of the coots contained consistently higher concentrations of radiomaterials than any of the ducks with the exception of Gadwall No. 2 and Wood duck No. 1. In feeding, the coot is primarily a dabbler and grazer (Jones, 1940), picking up its food from near the surface of the water and often from along the shore, but it is an excellent diver as well. The coot is omnivorous, but approximately 90 percent of its diet is plant materials of which about 40 percent was leafy aquatic vegetation and about 14 percent algae. However, in White Oak Lake there are no leafy aquatic plants, and evidence from the food material observed in coot stomachs during dissection indicates that algae made up considerably more than 14 percent of the total diet. The gadwall is one of the few surface-feeding ducks that can and does dive for its food, although that habit is indulged in only when necessary (Kortright, 1943). Also, approximately 10 percent of the normal diet of the gadwall is algae. The wood duck feeds primarily on vegetable material which consists mostly of acorns, nuts, seeds, etc., from trees and shrubs that usually grow on high ground away from the water's edge (Kortright, op. cit.). However, about 20 percent of the diet is usually made up of parts of aquatic plants. One of the wood ducks dissected during the present study was an immature male that was found shortly after it had died, presumably of natural causes. That individual was one of a brood that had been reared near White Oak Lake and had spent its lifetime there. All of the other ducks dissected and assayed had apparently used the lake primarily as a resting place and had left the area frequently in search of food. For these, and perhaps other reasons as well, it seems probable that the amounts of radiomaterials accumulated in the tissues of Gadwall No. 2 and Wood duck No. 1 more closely resembled those of the coots, which spent nearly all of their time at the lake, than those of the other ducks. Accordingly, in this study, the 18 coots, one gadwall, and one wood duck will be considered as having spent the majority of their time feeding at White Oak Lake, whereas the other birds will be considered as having used the lake primarily as a sanctuary.

The average amounts of radioactivity, in counts per minute per gram, fresh weight, accumulated in the different tissues of the birds feeding primarily at White Oak Lake, as compared with those of the birds feeding elsewhere, are listed in Table 29. From these data, it is obvious that the birds of the first category accumulated considerably greater amounts of radiomaterials than those of the second. The only tissue from the ducks which used the lake largely as a resting place that contained radioactivity anywhere near comparable to those of the other birds was the

Table 29. Average amounts of radioactivity, in counts per minute per gram, fresh weight, accumulated in the different tissues of 19 migratory waterfowl which fed primarily at White Oak Lake, and 30 birds that used the lake primarily as a sanctuary, Roane County, Tennessee

	Birds feeding primarily at White Oak Lake	Birds using White Oak Lake primarily as a sanctuary
Feathers	590	320
Eyes	390	15
Bill	3,250	160
Brain	670	25
Skin	790	30
Muscle	1,830	50
Heart	1,610	55
Thyroid	1,860	120
Trachea	2,980	190
Lung	1,310	50
Pancreas	4,120	140
Spleen	2,730	60
Liver	2,300	80
Gizzard	1,120	40
Intestine	2,280	100
Caeca	2,030	130
Kidney	2,130	90
Adrenals	2,740	90
Long bone	3,400	340
Ovary	2,080	120
Testes	2,250	75
Contents of gizzard	3,160	520
Contents of intestine	3,080	420
Contents of caeca	17,060	1,020
Contents of rectum	4,780	490

feathers, whereas all other tissues of those birds of the second category contained only relatively small fractions of the amounts accumulated by individuals of the first category.

Of particular interest are the amounts of radiomaterials accumulated by the tissues that are commonly used as food, such as the flesh, skin, and giblets. Approximately half the live weight of any waterfowl is made up of those tissues and the flesh constitutes by far the majority of the total, and ranks second among the five tissues in the accumulation of radiomaterials (Table 29). If it is assumed that each of the birds containing the larger amounts of radioactivity had 11 ounces of edible tissues in its body, and the amounts of radiomaterials in the flesh were representative, the average bird in that category carried a burden of more than 2.5 microcuries of radioactivity in its edible tissues alone. In addition, there was at least that much more in the other tissues of the body. Thus, the average bird in this study, which fed consistently at White Oak Lake, but for unknown periods of time, accumulated a total body burden of at least 5 microcuries of radioactivity.

Radiochemical analyses of samples of breast muscle from two of the coots showed that practically all of the radioactivity was emitted by phosphorus 32. Such phosphorus was, in all probability, accumulated in the muscle tissue as adenosine triphosphate during the phosphorylation processes. It should be mentioned here that the samples of the tissues taken for radioassay were usually counted about three or four days after the birds were caught. Inasmuch as the physical half life of phosphorus 32 is approximately 14 days, there was time between capture and assay for considerable decay. Thus, since no corrections were made for decay, the amounts of radioactivity in the birds at the time of capture were undoubtedly higher than the data in the various tables indicate. No radiochemical analyses of any of the other tissues were made, although aluminum absorption curves prepared from some of the samples of bone indicated that at least half the radioactivity in those samples was emitted by radiostrontium.

Calculations of the amounts of edible tissues in each of five coots, two gadwalls, and two mallards that could be consumed by man without exceeding the accepted maximum permissible concentration of phosphorus 32 are listed in Table 30. From these data, it is apparent that any one of the birds that fed primarily at the lake (the five coots and the gadwall captured March 3) would have supplied any human individual with considerably more than the permissible amount.

Table 30. Amounts of five edible tissues from three different kinds of waterfowl, in pounds, that could be consumed by man each day, without exceeding the accepted maximum permissible concentration of phosphorus 32, White Oak Lake, Roane County, Tennessee. The dates indicate the time of capture for each bird, during the winter of 1951-1952.

Tissue	Coots					Gadwalls		Mallards	
	11/9	12/3	12/17	1/24	2/18	2/8	3/3	12/17	1/25
Liver	.09	.19	.17	.10	.08	.39	.09	23.8	5.0
Heart	1.00	.33	.26	.22	.10	1.00	.16	17.6	7.0
Muscle	.42	.27	.31	.21	.15	1.50	.18	42.8	5.0
Gizzard	.60	.48	.31	.29	.18	1.40	.17	42.8	10.7
Skin		.60	.27		.34		.26	23.8	4.3

ACCUMULATION OF RADIOMATERIALS BY OTHER VERTEBRATES

This section includes the results of dissection and radioassay of 27 miscellaneous vertebrates as follows: two bullfrogs (Rana catesbiana), one cumberland turtle (Pseudemys scripta troostii), two map turtles (Graptemys geographica), two soft-shell turtles (Amyda ferox spinifera), three snapping turtles (Chelydra serpentina), one blue racer (Coluber constrictor), three green herons (Butorides v. virescens), two American egrets (Casmerodius albus egretta), one belted kingfisher (Megaceryle a. alcyon), seven muskrats (Ondatra zibethica), two raccoons (Procyon lotor), one gray squirrel (Sciurus carolinensis), and one woodchuck (Marmota monax).

Each of those animals was taken to the laboratory, killed, dissected, prepared for radioassay, and counted in much the same manner as that described for the waterfowl.

The amounts of radioactivity, in counts per minute per gram, fresh weight, accumulated in the different tissues of the frogs and turtles are listed in Table 8 of the appendix to this section of the report, whereas similar data for the birds are listed in Table 9, and those for the mammals in Table 10 of that same appendix. The various tissues of the snake contained only small amounts of radioactivity and are not included in the table.

Neither of the bullfrogs had accumulated much radioactivity in any of the tissues sampled although they had probably spent a considerable portion of their lives in or near White Oak Lake. Both of those animals were females and were captured in hoopnets during October 1952. Actual counts of the numbers of eggs in the ovaries revealed that one individual contained 11,740 ova and the other contained 12,390.

All of the turtles had accumulated relatively large amounts of radiomaterials in the various parts of the skeleton, which on radiochemical analysis was shown to be mostly radiostrontium. The bones of one snapping turtle, which had been found dead in one of the nets during the fish population study in the spring of 1952, were allowed to remain on the lake bank exposed to the natural elements for about a year. In March 1953, the humerus and femur of that animal were assayed, and it was found that approximately 2,800 counts per minute per gram of radioactivity was still present. Aluminum absorption curves of the radiomaterials in those samples revealed that it was almost pure strontium 90 together with its yttrium 90 daughter.

Although the wading birds and the kingfisher spent a large part of their time searching for food and feeding at White Oak Lake, none of the tissues contained very large amounts of radiomaterials. The relatively large amount of radioactivity in the sample of the bill of Green Heron No. 3 was probably caused by silt particles that had adhered to it. However, that particular bird had accumulated greater amounts of radiomaterials than any of the other birds of that species. Inasmuch as all of those birds migrate to other parts of the western hemisphere, any of the radiomaterials that they accumulate during their stay at White Oak Lake is carried with them.

Among the mammals, the most interesting was Muskrat No. 7. That animal was caught near White Oak Creek in the 4500 Area of the Oak Ridge National Laboratory. During its stay in the area it had accumulated a very large amount of radiostrontium throughout its skeleton, presumably from feeding on contaminated plants of its own choice. The figure of 246,000 counts per minute per gram (1.1 microcuries per gram) in the long bone as listed in Table 10 of the appendix, is an average of four separate samples taken from different parts of the skeleton. That animal had developed an osteogenic sarcoma at the proximal end of the right tibiofibula which had metastasized to the lungs and kidneys. A complete case history of that animal has been prepared by Dr. Krumholz and Lt. Col. John H. Rust, Veterinary Corps, U. S. Army, and has been accepted for publication in the Archives of Pathology. The date of publication is unknown but it is presumed that it will be out in 1954.

None of the other mammals had accumulated as much radioactivity as the muskrat mentioned above. However, all of the other muskrats had considerable amounts of radiostrontium in their skeletons. The raccoons and squirrel, which are not generally considered as aquatic mammals, had accumulated only very small amounts of radiomaterials. The woodchuck, on the other hand, was an immature female, probably not more than a few months old, that was caught while feeding on plants growing at the edge of the Settling Basin. If that animal had continued to feed in that area for a long period of time, and continued to accumulate radiomaterials as rapidly as it had during its relatively short lifetime, it may well have suffered the same fate as Muskrat No. 7.

BANDING OF MIGRATORY WATERFOWL

Although White Oak Lake is a relatively small body of water as compared with nearby reservoirs of the Tennessee Valley Authority, practically all species of migratory waterfowl which pass through eastern Tennessee have been observed on the lake during the course of a winter season. At that time the birds tend to congregate there, especially during the hunting season and periods of inclement weather. The presence of such large flocks of waterfowl raised the question as to whether the birds were all members of one large flock that remained in the vicinity, or whether they belonged to a succession of small flocks which passed through the area and stopped only for short periods of time.

The only successful method for obtaining information on the movements of waterfowl into and out of an area is one in which the birds are trapped, banded, and released. This method, of course, depends on the success of catching the birds and the recapture of individuals which have been banded previously. In addition, information on the movements of such birds is obtained from reports of banded individuals killed by hunters in various parts of the country. Accordingly, a program of banding waterfowl at White Oak Lake was inaugurated in September 1952 in cooperation with the U. S. Fish and Wildlife Service and the Tennessee State Game and Fish Commission.

Materials and Methods

During October and November 1952, one trap of customary design for trapping waterfowl was used. That trap was constructed of a frame of 2 x 4 pine lumber, having outside dimensions of 16 feet by 8 feet and 6 feet high, with the top and three sides covered with one-inch mesh poultry wire. One end was designed with two doors the height of the trap, hinged at the corners of the trap, and angled towards the center to form a V-shaped opening four inches wide. The trap was set in about 12 inches of water near the upper end of the lake over a soft mud bottom and baited with shelled corn. Unfortunately, the corn settled into the mud and hence was not available to the birds. Accordingly, several floating wooden platforms of one-inch material were constructed with one-inch strips around the upper edge so that the corn would not wash off. These platforms, about 18 inches wide and 4 feet long, were placed in the trap and baited. Apparently such baiting was attractive to wood ducks inasmuch as many of them were caught.

However, as the season progressed, it became evident that the more wary species of waterfowl, although present on the lake in large numbers, were avoiding the trap. Also, the wood ducks learned rapidly that the entrance to the trap served as a ready exit. The trap was modified by removing much of the wooden structure and replacing the one-inch-mesh wire with some having a mesh of two inches. The entrance was also redesigned to serve as a funnel. The doors were removed and poultry wire fastened in place so that there was a concavity about 18 inches deep from the front of the trap. That concavity led into a tunnel of poultry wire about 6 inches wide, 16 inches high, and 16 inches long, along the floor. A door was placed at the rear of the trap so that the operator could enter and handle the birds. The trap was moved to a new location where the bottom was firmer. Immediately following this renovation of the trap, the catch of birds increased and remained good for the rest of the season.

Two smaller traps, having the same features as the larger one, were constructed and placed in different locations. Those structures were 8 feet long, 6 feet wide, and 5 feet high, and the entire trap enclosed with two-inch-mesh poultry wire. These smaller traps were easily constructed, and contained a minimum of materials. As a result, they were very light and two men could easily transport them from one part of the lake to another whenever conditions warranted.

The tunnel was very effective in retaining the birds in the traps and apparently did not deter them from entering. Because of the length and narrow width of the tunnel, no bird was able to turn around and go back once it had started in. Once in the trap, the birds were usually unable to discover the point of entrance and frequently walked over or past the tunnel without noticing the opening. The height of the tunnel permitted a trap to catch ducks even though the water level rose as much as 12 inches in the tunnel.

All of the traps were baited with shelled and ear corn and the ducks were removed from the traps each morning seven days a week. Only very rarely did the ducks enter the traps before dusk, so it was not necessary to run the traps more than once a day. Trapping continued well into the spring until it became apparent that the only birds remaining in the area were nesting. Thus, the entire trapping season extended from the second week in October 1952 until the first week in May 1953. Only during the last few weeks of the study were the traps left open during the week ends.

The following migratory waterfowl were observed on White Oak Lake during the trapping season of 1952-1953:

Pied-billed grebe - *Podilymbus podiceps*

Florida gallinule - *Gallinula chloropus*

American coot - *Fulica americana*

Canada goose - <u>Branta canadense</u>

Mallard - <u>Anas platyrhynchos</u>

Black duck - <u>Anas rubripes</u>

Gadwall - <u>Chaulelasmus streperus</u>

Baldpate - <u>Mareca americana</u>

Pintail - <u>Dafila acuta</u>

Green-winged teal - <u>Nettion carolinense</u>

Blue-winged teal - <u>Querquedula discors</u>

Shoveller - <u>Spatula clypeata</u>

Wood duck - <u>Aix sponsa</u>

Redhead - <u>Nyroca americana</u>

Ring-necked duck - <u>Nyroca collaris</u>

Greater scaup - <u>Nyroca marila</u>

Lesser scaup - <u>Nyroca affinis</u>

Buffle-head - <u>Charitonetta albeola</u>

Hooded merganser - <u>Lophodytes cucullatus</u>

Red-breasted merganser - <u>Mergus serrator</u>

Ruddy duck - <u>Erismatura jamaicensis</u>

Banding Operations

During the season of 1952-1953, a total of 649 waterfowl were banded and released at White Oak Lake as follows: 390 mallards, 137 wood ducks, 96 black ducks, 17 coot, 6 pintails, 1 gadwall, 1 baldpate, and 1 green-winged teal.

During the early part of the season, it became obvious that only a small percentage of the birds that visited the lake were being caught. Even though the catch increased after the two small traps were put in operation, it was still apparent that relatively few of the transient birds were being banded. On several occasions, following heavy rains, the traps became flooded out and the birds could not enter them. Although no actual counts were made, it was estimated that fewer than 10 percent of the birds that visited the lake entered the traps. Thus, inasmuch as 649 waterfowl were banded, it seems plausible to say that upwards of 6,500 migratory waterfowl visited White Oak Lake during the winter season of 1952-1953.

Mallards. During the trapping operations, a total of 390 mallards were banded and released. The sex ratio among the banded birds was 99 males : 100 females, and is believed to be representative of the population as a whole. It was estimated that about 4,000 mallards visited the lake during the 1952-1953 season.

Mallards were among the earliest waterfowl to arrive at White Oak Lake in the fall of 1952. Small flocks, usually two to ten birds in number, appeared as early as the last week in September, and continued to arrive occasionally until late November. The main flights of mallards began to arrive about the middle of December and reached their peak abundance during the first week in January. During that period they outnumbered all other species. Following January 10, when the hunting season closed, the mallards virtually disappeared from the lake for a period of about three weeks. However, during the first week in February, about 25 percent of the banded birds returned to the lake and remained in the vicinity for the rest of the month. During March, the banded birds taken in the traps bore numbers which had not been recorded for several weeks. Furthermore, those birds were usually paired off and spent only a relatively short time at the lake, indicating that the northern migration was in progress. The catch of mallards tapered off until April 21. After that date, none were seen on the lake.

Of the mallards banded, 340 (87 percent) were handled before January 10, as indicated in Figure 9. The remaining 13 percent were banded largely during February, and may well have been with the flocks that visited the lake earlier, but for some reason or another did not enter the traps.

Although large numbers of mallards were not banded at White Oak Lake until late December, 11 of those banded birds were killed by hunters before January 10, and another was caught in a trap on January 19. The following list indicates where and when the birds were killed:

Alabama

Jackson County between December 31 and January 7

Kentucky

Muhlenberg County between December 20 and January 10
Wayne County, January 8
Jessamine County, January 9
Nelson County, January 10

Tennessee

Loudon County between January 2 and 10
Grainger County, January 3
Jefferson County, January 6
Loudon County, January 7
Smith County, January 9
Marion County, January 10
Loudon County, January 19 (trapped).

From the data at hand, there seems to be good evidence that the mallards under observation had finished their southern migration, and were wintering in the general vicinity of eastern Tennessee within a radius of approximately 100 miles of White Oak Lake. Birds banded at that lake were killed in Kentucky, Alabama, and Tennessee within a relatively short time

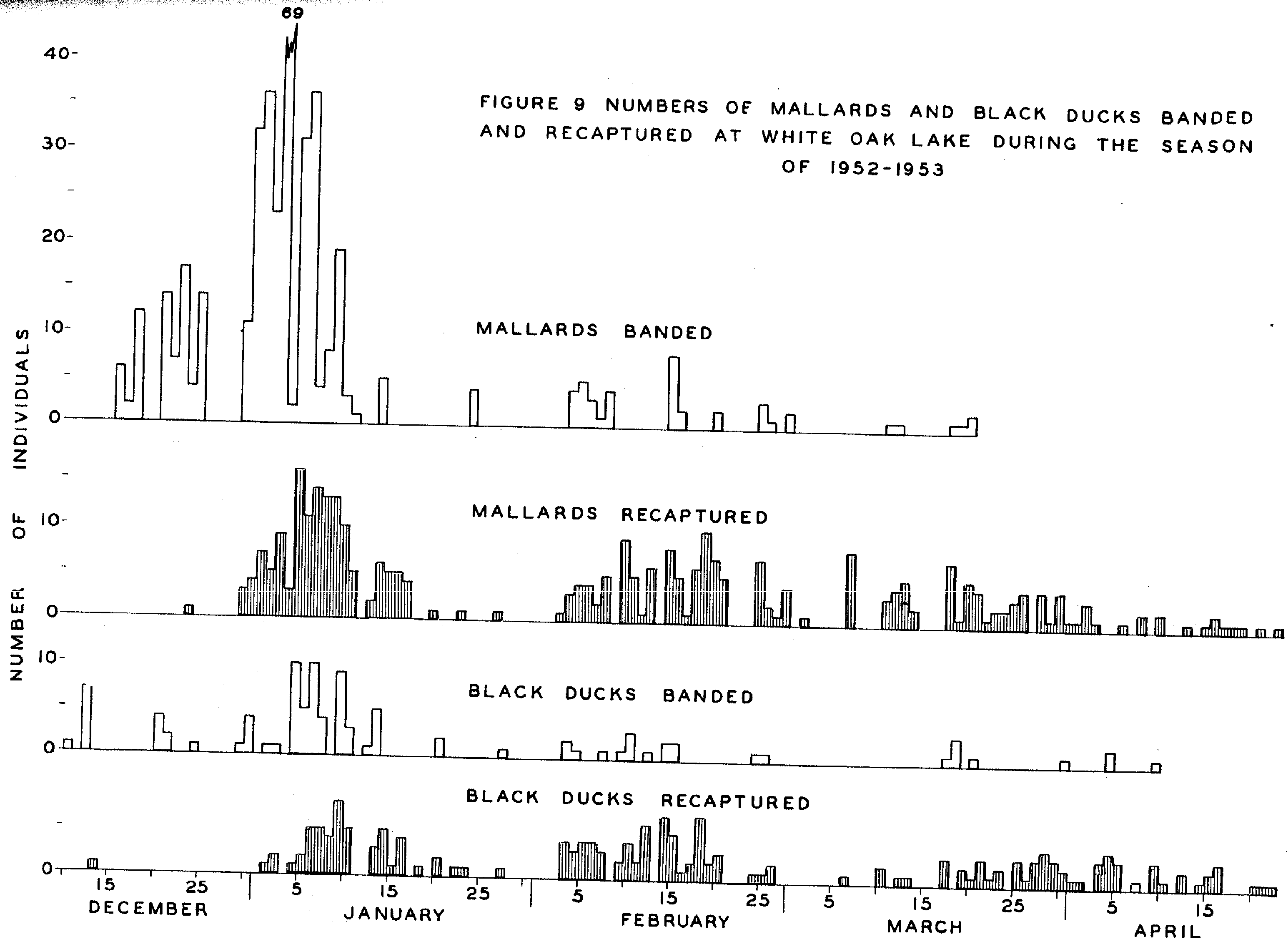


FIGURE 9 NUMBERS OF MALLARDS AND BLACK DUCKS BANDED AND RECAPTURED AT WHITE OAK LAKE DURING THE SEASON OF 1952-1953

after banding. Many of the banded birds were recaptured at intervals throughout the season. Inasmuch as the birds generally dispersed from the lake after the hunting season closed, it is apparent that the lake provided a sanctuary from the hunters during the open season. Certainly, hunting pressure has never yet been a deterrent to migration of waterfowl.

Several of the paired birds seen during the early spring consisted of a drake mallard and a hen black duck, and several of the birds taken in the traps were hybrids between those species. All of the hybrid individuals which appeared to be about half mallard and half black duck were males, and slightly larger and heavier than adult birds of either of the parent species, perhaps a manifestation of hybrid vigor.

Black ducks. During the trapping operations, a total of 96 black ducks were banded and released. The sex ratio of the banded birds was 129 males : 100 females, and is considered as representative of the population as a whole, even though there were relatively more males than among the mallards. The females appeared to be more susceptible to recapture than the males. It was estimated that about 1,000 black ducks visited the lake between September 1952 and April 1953.

The black duck is similar to the mallard in many respects except in coloration, and is considered to be much more wary. The pattern of utilization of White Oak Lake by the black ducks was very similar to that of the mallards, although the black ducks were only about one-fourth as abundant (Figure 9). They arrived at the lake in small numbers until December and then built up to a peak abundance the first week in January. They, too, left the lake for a period of about three weeks after January 10, but when they returned in February they were outnumbered by the mallards by only 38 percent. The decline in numbers through March and April closely followed that of the mallards.

The percentage of banded black ducks recaptured was considerably higher than among the mallards. Of the 96 birds banded, there were a total of 181 recaptures, but only 44 percent of the individuals banded were recaptured. The other 56 percent were not recaptured at any time. Many of the banded black ducks were recaptured throughout the season indicating that those birds preferred to stay in the vicinity of White Oak Lake once they arrived there.

Then, too, only two of the banded black ducks were killed by hunters, and both of those in neighboring counties (Loudon and McMinn).

Wood ducks. A total of 137 wood ducks were banded and released at White Oak Lake during the 1952-1953 season. The sex ratio of the banded birds was 132 males : 100 females. The rate at which the birds were recaptured also indicated that the males were more vulnerable to trapping. Thus, it is believed that the sex ratio of the entire population of wood ducks was much closer to a one to one ratio than indicated by the birds banded. Perhaps as many as 1,000 wood ducks visited White Oak Lake during the 1952-1953 season.

The natural environment of the White Oak Lake area is particularly attractive to wood ducks. The dense vegetation along the creek bottom provides adequate cover and a wide variety of food. During the fall of 1952, more than 100 wood ducks were observed rising from the lake at one time. The birds began to arrive at the lake early in October, but none were caught in the trap until late that month. Wood ducks were caught or seen every day until December 4. At that time they left and did not reappear until the middle of February. The flocks seen in the spring were generally small, never exceeding 10 birds. At this time of the year they did not enter the traps frequently. Only four of the birds banded during the fall were recaptured during the following spring.

Of the 137 wood ducks, 128 were banded during a 30-day period in the fall and the remaining 9 were banded during February, March, and April. The number of recaptured wood ducks was relatively high (23 percent) considering the short time they spent on the lake. Only eight birds were recaptured later than seven days after being banded.

Information on bands from five wood ducks was returned by hunters who had killed them. All of those returns were from areas to the south and southwest of White Oak Lake, as follows:

Alabama

Lamar County, November 24

Louisiana

Baton Rouge Parish, November 1952

Tennessee

Obion County, November 24
Polk County, November 29

Texas

Shelby County, December 3.

The complete disappearance of wood ducks during the winter months, and the return of information on birds killed by hunters to the south and southwest, indicates that that species prefers a milder winter climate than that afforded at White Oak Lake. From the meager data at hand, two wintering areas are suggested, one in northern Alabama, and one near the lower end of the Mississippi River.

Early in the summer of 1952, one hen wood duck, along with 12 ducklings, was observed on White Oak Lake. It is suspected that other birds nested in the area but no other young were seen.

The modified funnel entrance helped considerably in retaining the wood ducks once they had entered the traps. In the first trap, made with a V-shaped entrance, these birds would frequently enter and leave at will.

Coot. A total of 17 coot were banded and released at White Oak Lake during the 1952-1953 season. However, 7 of those birds were killed and used for radioassay at different times during the winter. Because of the difficulty in determining sex from external characteristics, no sex ratio was established for this species.

There is no evidence that coot migrate farther south than White Oak Lake. Rather, the birds that came to the lake during the fall, remained there for the winter. Nine birds arrived at the lake about the middle of October and by the end of the month the remainder of the entire winter flock of about 30 birds had accumulated. Inasmuch as there was an abundance of natural food present, the coots were not attracted by the bait in the traps. However, off and on during the entire winter, occasional coots were caught and banded.

Gadwall. The first few gadwall arrived at White Oak Lake in October, and it is believed that those birds remained in the vicinity for most of the winter. Other individuals arrived at intervals, and at one time a flock of about 100 gadwall was present. One of the preferred foods of the gadwall is filamentous algae, and the birds frequented those parts of the lake where mats of that plant material were abundant. The gadwall paid no attention to the bait in the traps, even though a variety of bait materials was used. Although one gadwall was caught and banded, it is believed that that bird merely entered the trap while associating with other ducks.

Gadwalls were present on the lake in varying numbers until late February when they began to leave. A few birds, however, remained until April 23. After that date none were seen.

Green-winged teal. A flock of 18 green-winged teal arrived at White Oak Lake early in October and stayed in the vicinity all winter. Although they spent some time at the lake, they preferred to stay in the area of the Intermediate Pond. One of these birds was caught and banded. The entire flock left the area about the middle of January and did not return. Whether they went north at that time is unknown.

Pintail. A few of these birds appeared at White Oak Lake about the middle of November. At that time two immature males were banded and released. Occasional pintails were seen on the lake during the winter, usually in association with other species. Four female pintails were banded and released in February.

Baldpate. Baldpates were comparatively scarce, and when they were seen it was usually in the company of a larger flock of gadwall. The first individuals of this species were observed in October and small flocks were seen intermittently until April. One hen baldpate was banded and released.

Other species. Representatives of one species of goose and eight other species of waterfowl were observed on White Oak Lake during the 1952-1953 season.

Six Canada geese used the lake as a resting spot at night for several weeks. They usually arrived at the lake at dusk and left early the following morning.

The diving ducks of the genus Nyroca were represented primarily by the lesser scaup. Occasional pairs of this species was present and, in a few instances, as many as 12 birds were observed. The greater scaup was only a rare visitor. A few ring-necked ducks and redheads were also seen occasionally.

The blue-winged teal appeared early in the fall and as many as 20 birds were frequently seen. However, they never stayed in the vicinity for more than a few days.

Ruddy ducks, shovellers, and buffle-heads were rare visitors, and never more than about six individuals were observed at any time. Pairs of shovellers revisited the lake occasionally all winter.

About eight pied-billed grebes were on the lake almost continually throughout the winter. These fish-eating birds are not gregarious, and only one or two individuals were seen at any time.

The red-breasted merganser was a very rare visitor on the lake and never stayed more than a few hours.

A flock of about 12 hooded mergansers were observed on the lake occasionally throughout the winter. It is assumed that they wintered in the immediate vicinity.

Two immature Florida gallinules stayed on White Oak Lake during October. Much like the coot in their habits, they remained almost constantly on the water.

Route of Migration

The main flyways used by migratory waterfowl have become fairly well established by the banding and recapture of birds at various locations all over the continent, and by reports of information on banded ducks killed by hunters. It is to be expected that the large impoundments of the Tennessee Valley Authority have had some influence in diverting waterfowl from the previously established routes of migration. The natural attraction of these large reservoirs to waterfowl is apparent, especially in those instances where adjacent areas have been dewatered and planted to food crops. Although their discussion was limited largely to the central and western parts of Tennessee, it has been pointed out by Wiebe, Cady, and Bryan (1950) that there is an awareness to the potentialities of the area by the following quotation from their paper:

> "The Tennessee Valley is rapidly becoming an important wintering area for waterfowl of the Mississippi Flyway because of (1) the possibilities created through the TVA developments, and (2) deterioration of coastal areas."

Even though no food crops have been planted on the reservoir properties in the eastern part of Tennessee, it appears that these large bodies of water in themselves have exerted a considerable influence on the migrating flocks of waterfowl.

From the meager data at hand, it is assumed that the birds which frequent White Oak Lake follow a route that leads from the eastern Great Lakes region along the rivers flowing in a southwesterly direction along the western slope of the Appalachian Mountains into eastern Tennessee. This assumption is supported by the fact that a duck banded in western Pennsylvania (the only foreign recapture in our records) was recaptured at

White Oak Lake, and that another duck banded at White Oak Lake was found dead in Haliburton County, Ontario, Canada, in April 1953.

The most plausible route of migration for such birds is south along the Allegheny River to the Ohio River. Then, instead of going west along the Ohio, they proceed south along the Kanahwa or the Big Sandy River to South Holston Reservoir, and thence down the Holston River into east central Tennessee. It is possible that this minor route of migration is familiar to other investigators and that the birds caught at White Oak Lake were merely members of a very large flock of which only one bird had been banded. However, if the use of this route is verified by additional information, it seems more reasonable to assume that there is a tendency for some of the birds to be deflected from the Atlantic Flyway by the Appalachian Mountains.

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APPENDIX

TO THE SECTION ON

VERTEBRATE BIOLOGY

Table 1. Amounts of radioactivity, in counts per minute per gram, found in various tissues of individual black crappies from White Oak Lake, Roane County, Tennessee, 1951-1953. The measurements for radioactivity for the first seven fish are not included in this part of the study. The stomach sample in all cases includes the pyloric caeca.

Date	7/13/51	7/24/51	7/25/51	7/25/51	8/10/51	8/12/51	8/22/51	8/22/51	8/23/51
Fish number	#8	#9	#10	#11	#12	#13	#14	#15	#16
	Counts per minute per gram of tissue								
Scales	5769	4611	3204	4569	3230	4578	2934	4156	4616
Skin	309	176	94	198	73	88	144	15	258
Muscle	204	170	101	70	74	82	99	144	121
Compact bone	10788	6453	3624	3473	4329	4651	5053	7848	8413
Spongy bone	4016	3742	2539	2732	2588	2627	2510	3390	2290
Dorsal fin	4175	3196	2163	1980	1294	2631	1311	3037	3160
Anal fin	4107	2777	1744	1872	1600	2430	2056	3516	2854
Other fins	5864	3934	2074	2294	2464	2534	2596	4198	2975
Gill filaments	519	256	97	183	-	241	161	296	148
Gill arches	4127	2734	1708	1622	2165	3223	2425	3605	3455
Eyes	198	175	70	144	120	120	141	143	119
Stomach	343	409	209	224	192	226	221	205	245
Intestine	610	229	-	142	171	487	262	146	438
Heart	-	553	402	283	246	232	148	-	279
Liver	534	674	381	341	382	356	411	532	367
Gall bladder	-	480	-	253	428	-	157	-	1091
Spleen	592	293	601	-	1238	484	697	-	-
Kidney	145	-	246	385	128	407	217	-	536
Head kidney	643	446	178	155	371	71	215	117	226
Central nervous system	200	193	139	381	190	132	104	59	204
Contents of intestine	629	380	256	333	244	269	543	306	273
Fat	141	90	73	80	90	-	33	49	118
Ovaries	-	-	55	-	250	-	176	-	-
Testes	508	856	-	202	-	112	-	376	386

Table 1. (Continued)

8/24/51	8/31/51	8/31/51	9/5/51	9/5/51	9/6/51	9/6/51	9/11/51	9/19/51	9/19/51
#17	#18	#19	#20	#21	#22	#23	#24	#25	#26
Counts per minute per gram of tissue									
2715	4966	4382	4370	4097	3083	3758	2903	3355	3338
150	25	215	157	194	95	129	169	105	223
37	67	53	94	55	36	58	57	34	50
4901	6991	7419	6603	6003	4972	4976	6420	5821	4891
1672	2423	2983	3089	2692	1234	2768	2498	2126	2254
1462	2414	2457	2829	2552	1776	2063	1995	1073	1722
1577	2165	2359	2959	1969	1533	1456	1499	2029	1646
2584	3722	2934	3189	2890	2491	2396	1902	2045	2643
147	201	169	209	140	114	175	110	110	146
2022	2770	2696	2247	2339	2034	2467	2074	1972	2171
77	146	128	104	124	93	80	112	96	83
127	219	240	209	222	230	198	111	153	114
433	80	205	92	448	253	114	439	314	259
-	233	-	356	301	51	16	337	282	706
257	614	509	576	448	393	458	426	325	466
292	251	-	1325	-	-	-	240	-	-
506	458	-	201	211	-	294	203	-	63
594	241	494	-	984	-	473	34	-	313
168	613	247	263	48	177	112	-	101	276
182	210	330	402	192	173	313	336	21	193
248	306	292	216	322	324	319	214	195	222
71	5	14	16	24	-	10	30	24	59
127	201	-	-	-	200	-	-	-	122
-	-	563	304	124	-	-	290	346	-

Table 1. (Continued)

9/20/51	9/21/51	9/26/51	9/26/51	9/27/51	10/1/51	10/4/51	10/4/51	10/9/51	10/10/51
#27	#28	#29	#30	#31	#32	#33	#34	#35	#36
Counts per minute per gram of tissue									
3072	2908	3343	3669	3605	3366	3936	4363	4835	4017
-	159	64	145	46	182	160	156	165	195
46	77	94	95	61	81	37	92	27	86
4670	5123	5628	5910	4587	6357	5635	6519	7750	6374
2188	2353	1930	2868	2521	2235	2966	3190	3476	2904
1390	1222	1742	1347	2112	1877	1583	2097	2683	2782
1278	1499	1493	1856	1769	1226	1968	2343	2390	2829
2058	1703	1776	1893	2490	3189	1999	2884	3319	3157
71	129	79	55	46	186	205	258	397	372
1680	1895	1956	2283	2316	2456	2389	2520	3347	883
58	65	101	59	113	98	97	103	164	159
399	165	90	164	234	260	273	391	544	457
205	84	144	108	209	24	404	380	725	579
28	562	335	-	526	298	342	65	-	542
253	266	396	498	481	453	773	741	984	945
-	609	99	311	295	-	306	235	-	787
-	300	49	622	1247	285	-	150	153	370
-	182	40	-	160	-	634	567	144	1228
-	197	181	299	273	187	355	262	294	458
102	45	102	192	231	152	135	413	348	-
551	1000	-	305	258	634	967	708	749	1212
17	47	34	2	45	4	29	64	38	36
79	-	129	-	-	153	-	-	-	343
-	187	-	350	306	-	282	294	891	-

Table 1. (Continued)

10/10/51	10/10/51	10/15/51	10/16/51	10/18/51	10/24/51	10/24/51	10/26/51	10/30/51	10/31/51
#37	#38	#39	#40	#41	#42	#43	#44	#45	#46
Counts per minute per gram of tissue									
6568	5393	4231	5637	3577	5058	4355	4018	5101	2786
340	171	-	232	206	76	241	2058	438	243
267	121	235	213	155	116	233	300	326	137
10784	10236	8585	-	5599	8316	7724	12754	9191	5636
4527	4131	3630	3543	3144	3600	3868	5363	4370	2890
3339	2764	3342	2775	1671	2272	3206	3954	2750	1845
2680	2618	2141	1913	2184	1690	2670	3538	2650	1956
4215	4300	3281	4390	2610	3444	4306	8370	4400	3120
494	408	430	645	470	372	726	654	724	355
3905	3009	3670	6038	2599	3104	5621	4337	5891	2415
224	174	182	253	149	84	247	313	240	139
793	630	942	909	788	775	892	1305	990	608
831	477	323	-	818	-	666	10137	1282	470
484	105	748	1151	477	705	683	7558	1090	449
1178	1043	1385	1755	882	786	1294	1476	972	671
193	127	428	546	549	622	554	20	418	-
428	533	656	2115	433	198	1073	8668	1073	580
157	1245	410	1022	746	599	964	295739	997	318
224	499	655	862	717	1921	798	1287	1150	588
471	363	360	260	531	345	439	3731	509	204
1041	1377	1556	1547	1559	1011	878	7536	1088	650
163	19	98	167	142	192	136	110	776	269
407	441	-	-	398	596	495	1842	-	367
-	-	730	990	-	-	-	-	1041	-

Table 1. (Continued)

11/1/51	11/6/51	11/6/51	11/7/51	11/13/51	11/13/51	11/14/51	11/20/51	11/20/51	11/21/51
#47	#48	#49	#50	#51	#52	#53	#54	#55	#56
Counts per minute per gram of tissue									
4980	4346	4488	3400	3790	4620	3675	3507	4008	3876
305	246	215	130	120	200	106	96	85	138
240	259	213	150	80	320	136	33	67	131
8565	8508	7826	7070	5220	7367	5494	4772	6444	5545
3698	3258	3125	3820	2540	4360	2776	2828	2902	2558
1984	2360	1835	3280	2060	1870	1666	1825	2317	2418
2304	2626	1976	1920	2170	2280	1627	1884	2351	2345
3459	3458	3082	2170	1864	3220	2270	2355	1898	2813
439	507	521	410	350	420	271	240	292	249
2757	3318	2663	2500	2220	2860	1675	1634	2540	2138
203	122	210	160	140	133	87	100	147	152
860	853	652	600	410	670	384	496	416	718
1225	11304	1267	710	520	300	464	562	304	807
7714	821	739	590	440	350	183	71	117	348
710	876	724	570	610	520	468	407	487	557
86	764	2056	190	160	-	266	-	82	-
1011	1019	1480	710	480	100	437	262	118	43
39	996	851	430	370	560	404	390	506	570
723	814	731	-	480	650	386	453	362	658
323	426	504	340	270	480	258	318	181	339
1437	754	832	450	290	1220	378	-	-	1303
182	151	237	110	30	150	51	69	112	96
-	808	-	890	-	400	251	198	-	369
597	-	606	-	440	-	-	-	343	-

Table 1. (Continued)

11/27/51	11/28/51	11/28/51	12/5/51	12/6/51	12/7/51	12/11/51	12/12/51	12/12/51	12/18/51
#57	#58	#59	#60	#61	#62	#63	#64	#65	#66
Counts per minute per gram of tissue									
3051	3008	3605	3077	3027	2621	2955	-	3298	3220
88	96	150	74	37	59	72	147	57	44
-	107	107	94	67	76	51	-	51	82
4869	5163	7168	5256	5616	5424	5353	6139	5529	6162
2253	2322	3379	2416	2759	2669	2593	2719	2939	3245
1481	1506	2160	1764	1577	1639	1762	1656	1612	1881
1555	1596	2204	1810	1744	1744	1981	1951	1315	2151
1777	1908	2534	2007	1468	1805	2179	2748	2062	2396
160	187	261	196	105	110	126	181	135	217
1851	2065	2177	1940	1774	1554	1515	2177	1775	2095
99	101	139	96	81	78	87	106	88	108
400	335	456	478	113	150	253	547	364	804
536	337	713	401	233	262	236	371	289	515
263	505	391	231	265	-	176	202	370	66
409	417	692	451	242	282	350	-	465	533
73	-	798	24	94	130	228	46	539	340
253	47	638	101	303	509	367	490	298	-
163	242	170	311	221	332	121	129	197	139
240	167	364	192	124	193	135	197	100	304
182	202	172	101	90	82	89	160	88	94
657	515	681	442	208	189	785	892	757	2239
42	28	102	100	44	70	-	64	51	111
302	-	352	293	-	160	-	-	-	-
-	289	-	-	154	-	163	265	146	125

Table 1. (Continued)

12/18/51	12/19/51	12/27/51	12/28/51	12/29/51	1/3/52	1/4/52	1/5/52	1/8/52	1/8/52
#67	#68	#69	#70	#71	#72	#73	#74	#75	#76
Counts per minute per gram of tissue									
3595	3101	3183	2479	1958	2740	3229	2936	2685	2435
21	58	97	31	47	62	38	34	98	20
53	48	76	25	22	32	45	40	39	24
6044	5885	5540	3962	4061	4134	5969	3441	5643	3536
3045	2597	2785	2395	2343	2240	2597	1455	1498	1913
1860	1387	1877	1798	1745	1270	1570	946	1468	1466
1957	1849	1990	1771	1396	1463	1698	1059	1326	1554
2390	2254	2037	1675	1667	1648	2398	607	1856	1830
164	110	122	72	89	79	97	80	103	53
1935	1823	1806	1341	1816	1531	1720	932	1089	1099
78	68	100	52	59	47	62	48	93	46
688	365	547	160	114	100	271	94	272	121
477	351	309	199	196	25	300	150	293	140
-	123	43	104	58	176	42	148	154	220
432	474	445	193	354	237	613	68	196	184
-	-	204	74	116	97	26	243	32	127
-	91	233	-	85	92	-	46	208	236
271	487	11	160	101	433	-	103	128	60
104	192	125	78	98	132	-	64	114	67
158	180	39	95	23	38	17	70	123	107
1971	834	233	176	219	127	309	284	383	30
163	59	34	38	64	4	93	47	49	20
146	-	201	94	-	-	-	67	161	114
-	99	-	-	123	98	124	-	-	-

Table 1. (Continued)

1/8/52	1/15/52	1/15/52	1/16/52	1/22/52	1/23/52	1/23/52	1/29/52	1/29/52	1/30/52
#77	#78	#79	#80	#81	#82	#83	#84	#85	#86
Counts per minute per gram of tissue									
2449	3042	4596	3154	2991	3004	3186	3151	2828	2568
-	14	111	45	34	80	50	84	105	31
33	22	44	34	41	40	39	50	39	22
4890	5591	4200	4200	5347	5700	5945	5747	5651	4770
3126	2094	2117	2488	2681	2035	1551	2801	2721	2208
1684	1780	1415	1681	1785	1885	1526	2025	2090	1670
1748	1772	1263	1645	1757	1346	1638	1942	1920	1622
1931	2306	1757	2172	2299	1756	1298	1751	2150	1962
109	95	38	170	92	31	63	105	84	48
1093	1914	1239	1622	1512	1664	1612	1190	1696	1299
74	55	62	70	62	64	61	54	61	44
219	214	68	243	148	130	86	110	274	93
-	249	-	230	277	299	-	175	173	108
131	164	278	-	514	69	100	418	113	179
407	127	168	509	307	254	347	131	468	107
212	258	-	274	313	149	-	119	1179	-
-	-	13	87	320	400	73	-	-	58
408	56	275	444	-	131	-	42	-	24
90	155	125	255	328	131	68	89	5	18
228	113	84	180	55	135	20	-	141	-
84	588	85	565	298	584	338	133	811	264
33	-	44	254	118	88	-	25	122	127
-	112	103	-	106	82	-	135	-	68
131	-	-	74	-	-	89	-	93	-

Table 1. (Continued)

2/5/52	2/5/52	2/6/52	2/12/52	2/12/52	2/12/52	2/19/52	2/20/52	2/21/52	2/27/52
#87	#88	#89	#90	#91	#92	#93	#94	#95	#96
Counts per minute per gram of tissue									
2560	3197	2630	2630	3459	2796	2880	2727	2935	2902
2	19	20	33	69	13	68	9	36	71
27	78	20	26	41	21	36	20	35	32
2642	5687	4522	4567	5493	5153	4581	4086	4877	4694
1287	2452	2021	2151	2289	1978	2291	1810	2433	2178
1152	1882	1411	1500	1826	1437	1494	1458	1661	1690
1527	1832	1289	1600	1783	1515	1740	1536	1644	1468
1645	2203	1961	1928	2319	2022	1742	1665	1748	1829
64	56	49	50	32	81	24	56	103	69
841	1838	1288	1104	1673	1535	1355	1215	1386	1496
10	(203)rt.eye blind	66	59	79	67	49	33	51	29
51	324	66	66	79	178	84	77	167	152
85	397	-	163	313	25	247	28	282	282
-	237	0	215	56	362	-	-	216	240
37	370	375	40	415	187	94	94	124	426
15	92	115	525	37	191	31	34	-	647
-	-	220	147	289	-	158	178	-	40
79	154	157	44	191	-	225	85	109	214
101	258	83	71	99	70	106	132	113	84
129	71	114	73	25	188	135	75	145	123
61	632	102	167	-	115	301	234	248	485
14	-	19	27	8	69	11	26	12	18
49	144	-	48	-	85	80	63	63	-
-	-	45	-	26	-	-	-	-	26

Table 1. (Continued)

2/29/52	3/1/52	3/4/52	3/4/52	3/5/52	3/11/52	3/11/52	3/11/52	3/19/52	3/19/52
#97	#98	#99	#100	#101	#102	#103	#104	#105	#106
Counts per minute per gram of tissue									
2625	2633	2603	2926	3413	2553	3341	2733	2731	2381
21	30	68	119	37	14	27	57	20	39
24	27	45	38	20	34	16	24	23	32
4233	6735	4686	4744	5215	5984	5689	4486	4552	4692
1968	2454	2300	2318	2554	1746	1726	2392	1999	2208
1204	1643	1498	1656	1889	1208	1863	1357	1643	1835
1372	1713	1498	1840	1815	1244	1775	1494	1674	1637
1646	1906	1677	2181	2142	1795	2078	1923	1798	1485
63	75	71	53	43	38	84	41	55	66
1177	1948	1378	1654	1271	1450	1695	1302	1544	1683
51	71	65	63	38	93	57	50	34	84
47	156	135	10	95	186	-	82	59	94
60	256	92	81	46	139	199	27	107	35
114	136	356	198	44	466	103	61	-	446
203	500	158	110	332	344	125	228	467	352
29	214	-	222	-	350	178	205	36	-
-	545	272	52	28	458	552	301	-	-
48	9	219	255	317	28	231	517	28	126
63	43	62	63	60	95	8	115	81	-
97	133	37	15	179	119	50	175	-	99
64	394	181	118	-	502	305	393	115	192
-	118	53	-	69	107	231	145	-	134
-	-	87	85	-	-	94	42	-	-
13	57	-	-	12	54	-	-	29	40

Table 1. (Continued)

3/20/52	3/24/52	3/24/52	3/24/52	3/31/52	4/2/52	4/2/52	4/8/52	4/8/52	4/8/52
#107	#108	#109	#110	#111	#112	#113	#114	#115	#116
Counts per minute per gram of tissue									
4945	2223	3222	3211	3274	1399	3095	4358	2658	2900
66	50	38	72	57	12	120	21	17	39
40	17	24	38	18	22	53	23	33	30
5322	4910	5087	5934	5646	3716	5904	4299	5394	4833
1505	2455	2611	2732	2530	3017	1902	2231	3060	2621
1504	1974	1802	2070	1988	1304	2440	1524	2360	839
1665	1972	1885	1929	1871	1853	2510	1607	2390	1680
2096	2272	2244	2268	2535	1666	2357	1829	2234	1500
39	55	107	55	34	72	117	36	99	89
1675	1583	1834	1578	1518	1613	1954	1382	1784	1651
63	31	69	50	56	56	74	49	89	60
92	94	232	133	180	55	357	144	232	218
167	66	308	162	370	169	528	269	60	285
404	14	419	187	-	-	248	58	134	248
89	385	257	285	617	398	762	356	608	634
-	23	196	139	231	-	131	-	260	208
-	444	247	727	317	-	-	103	236	174
-	139	93	-	145	66	103	155	333	-
128	94	110	67	75	-	56	-	-	-
192	129	152	179	96	93	94	58	6	33
225	644	448	272	287	512	432	175	381	335
63	208	147	220	495	74	-	-	-	-
67	-	141	124	-	-	-	-	-	-
-	23	-	-	72	44	108	23	85	44

Table 1. (Continued)

4/14/52	4/15/52	4/15/52	4/22/52	4/22/52	4/22/52	4/28/52	4/30/52	4/30/52	5/6/52
#117	#118	#119	#120	#121	#122	#123	#124	#125	#126
Counts per minute per gram of tissue									
2149	2545	2260	2729	2604	3524	3573	3525	3405	3697
113	86	77	92	93	88	189	-	84	251
11	58	47	94	54	60	154	102	96	146
4479	4379	4685	3968	4743	6048	5405	5625	5382	6211
2557	2202	2565	2490	2232	1743	2379	2841	2917	3226
1719	1835	1979	1567	1922	1877	2224	2009	2296	2506
1613	1853	1845	1686	1724	2100	1503	1565	2254	2441
1531	1993	2529	1712	2261	2762	2594	2740	1719	3188
160	185	198	41	148	130	372	316	354	652
1736	1556	1852	1055	1477	1812	2428	2139	2313	2756
61	97	91	102	64	106	87	140	114	168
276	658	657	341	378	575	940	837	708	1075
390	696	648	485	244	-	749	1041	367	1256
-	-	85	174	-	19	488	372	376	156
598	191	418	402	479	629	980	1059	991	1416
211	-	-	188	-	182	14	-	700	237
495	63	459	-	516	-	622	-	-	780
83	290	298	147	588	116	577	347	180	678
-	-	-	-	-	-	-	-	-	-
114	151	170	75	107	85	85	225	175	264
835	1539	1308	-	719	1104	1357	1371	1311	1947
This line becomes stomach contents from here on									
-	200	232	190	230	335	657	782	732	1400
56	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

5/7/52 #127	5/7/52 #128	5/13/52 #129	5/13/52 #130	5/13/52 #131	5/19/52 #132	5/19/52 #133	5/19/52 #134	5/26/52 #135	5/26/52 #136
Counts per minute per gram of tissue									
4582	3865	3297	2936	3978	4137	3291	3020	3374	9707
224	146	105	219	183	319	284	86	133	406
197	113	74	151	101	260	199	38	96	459
6832	5863	4941	6556	6830	7085	6738	8306	4534	16844
3056	3242	2895	2958	3641	3479	3311	2290	2734	5693
2249	2309	1863	2850	2596	2643	2928	2210	1671	5308
2611	2169	1408	2538	2548	1434	2647	1997	1822	5696
3427	2986	2235	2239	3015	3580	3675	2442	2151	7619
538	335	321	563	373	741	727	206	440	766
2958	2426	2200	3027	2846	3493	2984	1732	2412	4870
212	131	104	141	113	245	200	63	134	337
1183	867	681	1368	710	982	811	494	625	950
1608	1169	665	1419	921	889	794	462	503	920
1388	-	253	558	242	737	674	-	1042	948
1494	1026	850	1657	1104	1400	1522	1139	955	1851
488	15	82	614	701	-	502	198	299	589
1484	-	492	725	821	817	1071	-	708	1057
1126	854	557	780	389	1229	1014	516	655	948
-	-	-	-	311	1076	1008	270	586	1284
434	139	253	348	207	329	326	138	333	614
2185	1643	1510	3122	2143	1150	1268	4385	1055	-
Stomach contents		-	-	-	-	-	380	362	197
-	-	-	-	-	1653	1181	-	947	-
456	188	332	632	336	-	-	238	-	911

Table 1. (Continued)

5/26/52	6/3/52	6/3/52	6/3/52	6/10/52	6/10/52	6/10/52	6/17/52	6/17/52	6/17/52
#137	#138	#139	#140	#141	#142	#143	#144	#145	#146
Counts per minute per gram of tissue									
3947	4541	5248	6180	5472	5921	6354	4037	5770	10518
121	235	315	389	268	259	330	144	209	342
144	197	234	178	270	287	307	124	184	368
5290	7438	9133	10743	8766	9076	9967	5530	10131	19522
3229	4089	5817	5902	4918	5575	5540	2779	5845	10031
2519	2800	4087	4284	3628	4298	3799	2260	4819	7665
2086	2936	4008	3800	2848	3750	3730	2344	3771	7782
3416	4145	2550	4846	5191	6016	5808	2416	4866	8576
499	540	546	612	561	706	582	370	537	509
2542	3182	4578	4549	3738	4255	4523	2403	4607	6197
184	221	186	251	243	267	268	106	185	276
757	737	643	661	804	902	692	503	618	658
794	686	817	936	885	841	908	469	576	744
681	481	581	608	314	894	622	366	475	887
1060	1128	1232	1484	1296	1829	1599	670	1174	1653
-	-	362	-	682	1392	433	26	-	1240
386	724	664	677	1014	1039	587	10	559	71
501	1025	877	854	805	333	543	266	352	267
453	1049	1106	951	749	742	623	481	793	499
407	440	546	516	402	491	709	137	339	639
-	-	-	-	1079	1800	1152	1028	-	587
565	578	-	-	505	743	-	714	-	1055
1122	877	1136	-	-	-	-	274	522	-
-	-	-	320	627	940	819	-	-	363

Table 1. (Continued)

6/24/52	6/24/52	6/25/52	7/1/52	7/1/52	7/1/52	7/1/52	7/8/52	7/8/52	7/8/52
#147	#148	#149	#150	#151	#152	#152A	#153	#154	#155
Counts per minute per gram of tissue									
4701	5173	5239	7210	6912	5048	10952	4605	7410	5736
102	128	107	204	282	200	178	162	276	256
101	201	189	170	218	216	200	152	254	125
8084	10132	9456	9810	12834	8832	18424	7951	10288	11553
4509	4817	5508	5455	7046	7357	9561	4795	5753	6154
3512	3434	3316	2728	5283	4319	5840	3395	4268	2878
2488	3670	3812	4455	5044	3828	6889	2841	3915	4410
4154	5362	5508	5411	5377	4290	8293	3939	5571	-
392	362	531	524	585	558	466	504	546	477
3659	4783	5246	4773	6241	5067	6635	4589	5437	4980
171	228	197	204	268	218	126	173	249	-
440	213	637	698	728	769	513	850	736	254
359	530	616	576	734	809	945	784	1045	585
1150	1208	1813	778	539	507	495	867	1032	789
1013	1134	1308	1056	1062	1300	1859	1173	995	939
140	219	300	257	547	654	411	637	545	397
165	-	-	739	642	726	583	610	564	437
492	669	591	640	967	997	269	864	1301	681
514	362	582	414	869	844	697	710	1021	580
236	312	420	506	587	374	175	396	1402	400
369	793	719	776	817	813	1208	826	883	-
631	818	806	-	977	467	1297	919	751	909
415	-	-	628	-	-	-	-	629	581
-	545	968	-	-	-	-	-	-	-

Table 1. (Continued)

7/15/52	7/15/52	7/15/52	7/22/52	7/22/52	7/22/52	7/29/52	7/29/52	7/30/52	8/5/52
#156	#157	#158	#159	#160	#161	#162	#163	#164	#165
Counts per minute per gram of tissue									
5687	6442	5243	6972	8319	12840	8672	12155	7819	8321
381	415	194	395	360	684	506	538	383	260
347	130	108	274	308	454	287	357	328	230
7934	9734	10014	9665	13670	13034	11268	18719	13224	11008
4353	3348	6652	2445	7387	10578	6958	9180	7655	6148
3165	4362	4562	3633	4945	6763	5787	8026	2695	5065
3003	4955	4663	2635	5737	6301	5458	7357	5864	5147
2773/	5517	5694	5508	5803	9339	7575	9888	6861	5182
449	598	438	920	940	1076	765	978	948	568
4086	5104	5700	4974	5565	6477	6227	8008	6972	4868
308	249	218	315	339	427	374	436	365	308
601	827	603	1441	1135	1565	1092	1205	1196	632
717	942	544	1489	1479	1664	1262	1505	1201	1068
1057	712	469	621	1306	1280	791	976	741	700
1332	1533	1127	1577	1660	1695	1623	1871	1739	1530
888	497	571	224	521	446	592	947	381	491
905	1279	397	1229	1612	1011	981	1161	767	1130
665	796	613	801	807	478	541	754	828	386
807	1173	571	972	971	1004	564	645	1282	1945
554	549	451	485	508	670	688	766	633	499
1424	-	944	1714	1445	1595	1596	1339	1659	1617
623	-	1429	1437	1510	1080	1290	1446	1692	1236
-	-	589	-	-	944	916	-	905	-
-	-	-	N.S.	N.S.	-	-	N.S.	-	1132

Table 1. (Continued)

8/5/52	8/5/52	8/12/52	8/12/52	8/12/52	8/18/52	8/18/52	8/18/52	8/28/52	8/29/52
#166	#167	#168	#169	#170	#171	#172	#173	#174	#175
Counts per minute per gram of tissue									
8789	11078	7125	10175	9765	10661	7349	10630	8929	8633
243	293	191	288	205	266	270	240	322	213
274	359	251	269	260	199	190	219	213	210
12078	16413	9592	14630	15480	16026	9331	15388	13296	11119
6388	9140	4729	7878	7765	8558	5170	7402	7613	6135
4470	6497	2976	4174	6343	5182	4308	5296	6073	4658
3974	6261	3375	6000	6485	6710	3902	5850	5102	4909
6068	8780	4535	7746	7987	7737	5576	6788	4893	7183
557	704	429	494	507	573	535	624	546	424
5584	6909	3934	5715	6530	6122	4697	5433	5407	4218
310	370	260	373	289	339	230	298	281	216
773	879	545	622	629	540	595	621	502	490
641	651	587	622	963	589	475	881	497	647
526	917	438	694	114	473	650	607	621	333
1502	1622	805	1508	1507	1289	1216	1400	1102	1108
627	-	491	885	511	632	932	1813	108	334
938	8848	1085	1818	794	266	382	1361	-	593
	(not used)								
609	1414	252	625	603	495	671	1073	227	299
1089	876	323	1107	448	948	707	964	493	509
527	644	379	614	314	446	446	509	355	335
1080	1040	717	670	457	582	857	826	1269	930
1053	1083	523	1033	480	639	426	625	513	766
-	1076	656	-	-	701	-	-	-	848
924	-	-	644	-	-	No sample	No sample	609	-

Table 1. (Continued)

8/29/52	9/3/52	9/3/52	9/3/52	9/10/52	9/11/52	9/11/52	9/16/52	9/16/52	9/17/52
#176	#177	#178	#179	#180	#181	#182	#183	#184	#185
Counts per minute per gram of tissue									
7452	6350	8936	8408	8014	6907	8917	4384	8233	10638
208	157	106	127	202	117	128	120	111	125
186	87	164	169	152	133	146	69	148	53
11532	9880	11718	12976	12322	10992	9608	6488	10923	7275
7114	5479	6444	6480	5982	5055	6132	3807	5419	3350
4854	4184	4172	5260	4300	3808	4858	3087	5314	2617
4226	3859	4443	5047	3894	4167	4810	3382	4462	2578
5976	4348	6981	6662	3296	5722	6809	3699	6472	2264
368	315	438	414	392	269	367	213	279	203
5140	4442	4345	4698	4621	4177	4774	3904	3781	2929
214	194	228	273	241	186	199	142	187	130
472	346	507	504	514	346	432	265	340	311
316	409	348	348	665	531	696	232	209	431
560	594	139	380	1011	126	254	456	247	-
1167	793	961	1347	1095	956	1317	1284	1180	1106
352	71	74	-	470	-	346	335	158	212
773	203	-	1931	366	-	1676	-	-	-
380	416	900	1394	-	960	316	135	746	392
282	389	420	1071	391	247	243	-	365	209
587	318	474	440	308	553	338	132	351	289
1016	782	691	860	523	671	858	493	321	737
603	703	821	708	770	105	576	-	537	524
467	373	-	469	411	-	362	-	-	253
-	-	612	-	-	384	-	497	679	-

Table 1. (Continued)

9/24/52	9/25/52	9/26/52	10/1/52	10/1/52	10/2/52	10/6/52	10/7/52	10/7/52	10/13/52
#186	#187	#188	#189	#190	#191	#192	#193	#194	#195
Counts per minute per gram of tissue									
6435	7057	7607	5439	5698	5024	5949	5239	6355	5129
60	170	113	104	53	114	108	44	89	64
80	97	114	58	79	102	55	53	52	57
8337	11277	11276	8133	7756	7298	8547	7153	10726	7023
4072	5779	6477	4146	5204	3497	4764	4016	5721	3921
3646	4929	4973	3445	2807	3204	3424	2818	4011	3307
3984	4604	4973	3405	3390	2973	3613	3000	4421	2964
4073	5218	5595	3663	4231	3414	4434	3372	5286	3126
189	291	338	173	189	219	245	159	308	142
4101	3927	3742	3140	3695	3323	3174	3642	4185	2982
161	169	160	145	132	149	137	120	146	139
429	495	455	323	422	462	306	213	525	269
302	710	792	661	215	491	529	234	654	369
125	704	85	195	-	298	174	238	348	205
1031	1067	1210	642	934	1317	915	955	1476	959
497	851	742	115	386	1003	440	-	231	218
252	456	830	163	-	-	114	142	572	180
97	996	716	186	217	454	402	90	980	194
112	805	669	398	53	351	150	154	526	194
255	213	445	179	108	212	123	119	125	189
621	794	1081	-	-	936	622	637	785	742
1580	816	1344	1146	704	1067	1810	-	1080	926
196	377	177	257	292	-	-	-	-	-
-	-	-	-	-	577	422	333	713	377

Table 1. (Continued)

10/13/52	10/14/52	10/22/52	10/24/52	10/24/52	10/27/52	10/28/52	10/28/52	11/4/52	11/4/52
#196	#197	#198	#199-3	#200-3	#201	#202-3	#203-3	#204	#205
Counts per minute per gram of tissue									
6308	6059	4602	5284	4827	5626	5100	6193	4546	5011
132	133	91	45	64	66	50	33	51	38
88	72	44	55	37	39	40	43	34	39
9605	9852	6518	7945	8427	8621	7804	9565	6267	8090
5399	5199	3435	4304	4130	4361	4234	5062	3472	4094
3984	4260	2745	3056	3595	3322	3563	4371	2580	2765
4470	4083	3095	3326	3483	3131	3280	3824	2771	2976
4165	4883	3166	3180	3350	3577	3250	4604	3108	3514
196	225	159	146	96	106	150	139	112	98
3808	3472	2979	1593	2783	3059	2773	3203	2595	2615
150	125	100	86	104	91	89	102	93	102
263	400	239	236	168	202	265	375	152	175
300	226	243	234	117	138	264	569	187	215
116	-	227	328	161	191	10	184	97	225
875	1170	716	587	501	534	734	747	900	652
544	121	337	149	83	0	-	-	155	-
-	240	237	302	25	245	150	123	248	-
-	-	222	560	474	408	197	318	51	225
255	242	251	402	158	199	166	232	166	110
201	46	99	123	139	147	112	279	54	23
1812	478	396	169	271	-	326	488	497	383
870	1306	1372	460	-	-	-	1233	-	-
-	-	156	187	179	167	-	243	-	-
337	399	-	-	-	-	243	-	185	180

Table 1. (Continued)

11/4/52	11/11/52	11/11/52	11/11/52	11/18/52	11/18/52	11/18/52	11/25/52	11/25/52	11/25/52
#206	#207	#208	#209	#210	#211	#212	#213	#214	#215
Counts per minute per gram of tissue									
5125	4950	5015	5504	3604	4362	3836	3663	4299	4942
64	14	25	74	66	78	57	33	66	13
44	28	43	40	32	10	21	25	35	25
8944	6330	7260	9493	5646	7700	5810	5596	8690	8428
4361	3457	4517	4833	2985	4856	3608	2108	4405	4344
3864	2783	2868	4196	2694	3621	2657	2379	3297	3519
4154	2965	2933	4003	2191	3892	2547	2426	3299	3424
3108	2865	3168	4037	2454	3275	2443	2440	3389	3363
164	73	86	120	59	54	53	50	82	91
2999	3481	3032	3270	2129	2338	2557	2191	2355	2286
116	71	89	98	95	85	61	62	76	80
229	139	106	366	86	135	144	66	203	130
510	157	64	587	165	286	120	0	183	-
413	0	13	160	-	-	-	-	-	-
489	414	480	862	645	833	335	291	576	490
-	90	0	-	-	-	-	-	-	-
90	464	140	-	-	-	-	-	-	-
-	286	106	218	-	62	300	317	337	280
253	155	12	74	-	-	-	-	-	-
52	84	70	171	138	44	16	110	93	77
611	169	125	932	--	260	-	-	-	-
-	-	-	1797	-	-	311	-	-	-
152	128	-	-	-	-	81	75	-	-
-	-	120	131	100	86	-	-	102	55

Table 1. (Continued)

12/2/52	12/2/52	12/2/52	12/9/52	12/9/52	12/9/52	12/15/52	12/15/52	12/16/52	12/22/52
#216	#217	#218	#219	#220	#221	#222	#223	#224	#225
Counts per minute per gram of tissue									
4227	4353	4130	5000	5061	4383	3709	5152	4968	3803
49	12	40	34	20	60	36	33	47	62
31	31	23	54	28	22	24	32	24	28
7140	6557	6218	7873	6967	6409	6740	7700	7886	6247
2820	3726	3964	4417	3600	3852	3914	4647	4312	2678
3284	3119	2370	3623	2788	3127	2961	3492	3444	2440
3055	3534	2593	2903	2981	3036	2951	3742	3333	2348
3028	3015	2423	3163	3687	2905	2373	3268	-	2796
65	35	68	66	75	72	45	53	74	60
2619	2461	2352	2831	2890	2949	2729	2907	2376	2322
90	61	79	113	76	73	59	82	73	89
119	100	100	113	92	148	91	115	132	35
115	78	87	278	140	61	14	289	-	54
-	-	-	-	-	-	-	-	-	-
252	347	349	708	525	348	538	349	425	273
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
121	-	-	305	258	63	-	-	-	-
-	-	-	-	-	-	-	-	-	-
76	26	15	135	43	145	64	45	55	-
374	755	395	103	-	688	136	972	-	-
-	195	670	-	-	-	425	126	805	-
100	81	-	-	-	92	-	104	-	60
-	-	42	103	56	-	63	-	83	-

Table 1. (Continued)

12/22/52	12/22/52	12/30/52	12/30/52	12/30/52	1/7/53	1/7/53	1/7/53	1/12/53	1/12/53
#226	#227	#228	#229	#230	#231	#232	#233	#234	#235
Counts per minute per gram of tissue									
4540	4868	3766	4810	5243	4387	4852	5076	4450	5505
41	61	20	21	41	5	6	50	-	-
69	42	43	23	34	16	16	35	29	22
6286	7580	6160	8003	8910	6773	7082	7762	6465	10635
3262	3560	3659	4192	4498	3735	4009	4257	4015	5245
2286	2595	2725	3003	3420	2879	2821	3115	-	-
2888	2054	2877	3286	3315	2847	2940	3282	-	-
3237	3450	2630	2926	3209	2855	2554	3049	2295	3770
32	60	80	49	53	80	34	50	-	-
2250	2250	2179	2351	3054	2372	2605	2928	-	-
96	66	79	78	96	70	82	91	100	98
166	27	93	43	65	51	218	96	-	-
262	-	166	6	-	-	242	241	-	-
-	-	-	-	-	-	-	-	-	-
622	246	524	493	385	145	474	400	335	355
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
260	50	87	60	34	25	64	-	170	145
-	-	-	-	-	-	-	-	-	-
-	716	-	-	-	-	-	-	-	-
-	91	-	-	-	72	-	133	-	-
130	-	96	110	28	-	85	-	-	-

Table 1. (Continued)

1/12/53	1/12/53	1/19/53	1/19/53	1/20/53	1/20/53	1/26/53	1/26/53	1/26/53	1/26/53
#236	#237	#238	#239	#240	#241	#242	#243	#244	#245
Counts per minute per gram of tissue									
4525	4945	4545	4030	3640	4950	3875	3880	4260	5550
-	-	-	-	-	-	-	-	-	-
13	37	21	38	33	27	21	28	19	22
8755	9550	7740	6230	-	7700	5240	5000	6590	5600
4070	4471	4270	3600	3200	4800	2880	3220	3820	2270
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
2960	3695	3095	2810	2410	3355	2250	2000	3800	2970
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
71	85	87	95	75	100	65	60	60	85
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
490	529	560	540	150	430	310	465	170	630
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
91	0	105	6	55	65	85	18	13	90
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

2/3/53	2/3/53	2/3/53	2/3/53	2/10/53	2/10/53	2/11/53	2/12/53	2/17/53	2/17/53
#246	#247	#248	#249	#250	#251	#252	#253	#254	#255
Counts per minute per gram of tissue									
3340	3670	5150	4450	4110	3990	3820	4860	2620	3640
-	-	-	-	-	-	-	-	-	-
21	18	16	20	22	16	8	7	28	32
4780	6070	9060	7300	5850	6180	6130	7540	6170	6550
2650	3130	4880	3890	2540	3270	2500	3930	3350	3710
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
2590	2560	3870	3280	2370	2490	2740	3210	2340	2940
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
75	70	80	75	75	70	80	60	55	85
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
620	240	680	770	170	300	500	270	780	360
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
11	140	85	170	37	30	0	14	85	120
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

2/17/53	2/17/53	2/24/53	2/24/53	2/24/53	2/26/53	3/3/53	3/3/53	3/3/53	3/3/53
#256	#257	#258	#259	#260	#261	#262	#263	#264	#265
Counts per minute per gram of tissue									
4450	4180	3920	4860	5000	4390	3790	3650	3690	3450
-	-	-	-	-	-	-	-	-	-
21	31	21	21	50	21	30	22	24	15
6860	5300	5500	7350	6560	7040	6000	5050	6950	5510
3920	2850	3320	4740	2960	4640	3780	3350	4180	3060
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
2380	2530	1970	3600	3225	2900	2760	2770	3280	2400
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
90	85	60	100	85	65	70	60	80	80
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
110	340	230	720	540	555	645	260	600	185
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
45	7	90	0	0	0	70	0	0	0
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

3/10/53	3/10/53	3/10/53	3/10/53	3/18/53	3/18/53	3/18/53	3/18/53	3/23/53	3/23/53
#266	#267	#268	#269	#270	#271	#272	#273	#274	#275
Counts per minute per gram of tissue									
3700	4160	5060	5300	4035	4915	5320	4270	3770	3540
-	-	-	-	-	-	-	-	-	-
21	20	47	29	27	32	22	31	24	32
4850	6370	7260	7040	6515	7150	7965	6970	4930	5030
2720	2980	3810	3600	3815	4100	3815	3900	3420	3220
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
2460	2940	3780	3920	2475	3255	3165	3270	2700	2785
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
50	75	100	65	85	60	95	100	90	85
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
190	440	720	520	220	175	860	455	180	410
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
40	95	120	10	50	0	13	55	80	75
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

3/23/53	3/23/53	4/2/53	4/2/53	4/2/53	4/2/53	4/6/53	4/6/53	4/6/53	4/6/53
#276	#277	#278	#279	#280	#281	#282	#283	#284	#285
Counts per minute per gram of tissue									
4210	4550	5490	5670	4960	5510	4910	5620	4260	5080
-	-	-	-	-	-	-	-	-	-
23	25	34	80	32	34	28	54	34	55
6500	6840	8320	9920	7390	8180	7500	9550	6750	9090
4370	3600	5510	5150	4090	4810	4280	5090	4330	4830
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
3230	3090	4590	4470	3700	3850	3830	4470	3480	4550
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
57	100	105	125	90	100	80	110	285	120
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
210	215	1060	840	355	510	1130	1200	820	650
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
180	70	39	160	38	4	57	90	86	140
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Table 1. (Continued)

4/13/53	4/13/53	4/13/53	4/13/53
#286	#287	#288	#289
Counts per minute per gram of tissue			
3925	5150	5150	4250
-	-	-	-
80	70	75	65
5710	7375	5100	6270
3310	4010	3490	3890
-	-	-	-
-	-	-	-
2600	3970	3260	3140
-	-	-	-
-	-	-	-
152	135	120	105
-	-	-	-
-	-	-	-
-	-	-	-
935	815	655	890
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
85	285	350	175
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Table 2 . Amounts of radioactivity, in counts per minute per gram, found in various tissues of individual bluegills from White Oak Lake, Roane County, Tennessee, 1951-1953. The measurements for the first seven fish are not included in this part of the study. The stomach sample in all cases includes the pyloric caeca.

Date	7/18/51	7/18/51	7/19/51	8/8/51	8/9/51	8/10/51	8/15/51	8/16/51	8/16/51
Fish number	#8	#9	#10	#12	#13	#14	#15	#16	#17
	Counts per minute per gram of tissue								
Scales	2597	3627	2305	2511	2085	2444	4230	2364	2632
Skin	222	226	168	88	61	77	381	72	155
Muscle	120	207	100	135	72	83	194	107	127
Compact bone	2640	4130	2271	3650	2201	2975	7445	2990	2891
Spongy bone	1561	2500	1334	1600	975	1385	3997	1553	1567
Dorsal fin	1425	1916	1360	1285	825	1117	3925	1633	1049
Anal fin	2243	2468	1764	1452	1058	1230	4283	1663	2083
Other fins	2129	2776	1608	1410	1586	1582	3623	1688	1940
Gill filaments	235	500	233	203	135	90	386	212	262
Gill arches	1528	2898	1230	1036	514	1186	3201	1298	2264
Eyes	156	184	134	129	93	156	207	76	120
Stomach	396	521	237	203	169	249	431	213	307
Intestine	382	522	331	174	128	124	456	231	441
Heart	417	452	83	710	-	281	-	83	-
Liver	568	779	388	-	237	368	473	487	343
Gall bladder and contents	-	340	-	127	32	149	-	-	-
Spleen	719	736	480	595	-	370	-	272	-
Kidney	392	547	236	346	41	192	489	271	250
Head kidney	641	651	451	269	56	104	159	473	247
Central nervous system	218	490	59	145	82	65	209	163	103
Contents digestive tract	397	907	467	207	240	417	493	731	551
Fat	340	441	-	47	-	28	438	-	-
Ovaries	519	756	458	-	147	-	298	343	242
Testes	-	-	-	74	-	240	-	-	-

Table 2. (Continued)

8/16/51	8/24/51	8/28/51	8/29/51	8/29/51	8/30/51	9/5/51	9/6/51	9/10/51	9/11/51
#18	#19	#20	#21	#22	#23	#24	#25	#26	#27
Counts per minute per gram of tissue									
3003	1646	4148	3279	3945	3232	3194	4178	3553	2276
245	76	429	193	33	324	175	348	-	117
158	30	227	170	192	100	84	106	145	85
4760	2863	7455	7147	6136	5389	3945	6180	7204	2372
1869	1389	2122	1720	2576	2034	2086	2054	2543	1187
2243	1002	3358	3004	2129	1909	1610	2256	1714	1169
2912	-	4186	2953	2199	2546	2020	2634	2617	1320
2449	1224	4455	4523	3295	3171	2176	2961	2107	1314
150	132	314	334	381	215	166	413	442	113
1779	878	1906	1924	2062	1820	1031	1588	1703	899
142	78	276	184	179	152	135	161	68	63
333	138	453	359	480	266	184	281	247	192
-	46	343	146	482	346	159	374	204	125
535	31	288	-	441	1490	212	-	-	-
503	256	921	664	826	969	868	875	461	1048
145	807	-	519	-	-	1307	544	-	-
537	234	-	354	270	-	85	-	847	181
326	158	551	238	697	308	291	670	247	185
628	243	653	586	485	302	396	812	-	194
216	223	124	526	-	75	342	375	246	176
886	210	778	313	980	414	324	410	751	482
315	-	40	37	85	42	67	224	71	-
319	-	430	89	292	-	-	196	193	-
-	197	-	-	-	1333	130	-	-	195

Table 2. (Continued)

9/11/51	9/12/51	9/12/51	9/20/51	9/20/51	9/27/51	9/27/51	9/28/51	10/1/51	10/5/51
#28	#29	#30	#31	#32	#33	#34	#35	#36	#37
Counts per minute per gram of tissue									
3521	2524	3745	1520	4514	3013	2866	1803	2774	2504
739	860	107	26	70	91	49	32	82	180
70	67	127	42	55	73	21	51	73	67
5743	3915	5048	1915	3669	2096	4322	3055	3797	3627
2031	1359	2410	956	1778	1679	2127	1430	2051	1885
2204	1164	2215	773	1164	1592	1518	978	1521	1387
2213	1112	2273	910	1536	1436	1462	1423	1539	1607
3383	2140	2988	970	1869	1125	2075	1585	1943	1642
226	180	121	37	127	118	170	197	85	127
1946	682	1176	451	932	888	1220	847	1122	1145
118	86	90	126	81	103	80	91	76	103
248	176	193	80	155	204	131	211	239	286
256	128	168	54	40	218	57	127	154	274
410	-	-	144	177	391	46	24	-	272
1305	444	581	319	673	382	1091	1734	775	632
669	84	-	235	274	218	-	117	-	336
2984	118	-	22	176	264	-	-	120	370
380	194	228	64	103	196	155	334	68	150
249	114	-	122	177	36	298	371	265	326
101	11	260	14	119	124	145	151	156	35
542	229	380	691	248	452	427	279	809	468
34	24	17	42	69	72	64	132	83	176
-	98	-	-	-	124	-	-	-	-
958	-	-	42	147	-	188	-	521	258

Table 2. (Continued)

10/11/51	10/12/51	10/15/51	10/16/51	10/18/51	10/26/51	10/26/51	10/30/51	10/31/51	11/1/51
#38	#39	#40	#41	#42	#43	#44	#45	#46	#47
Counts per minute per gram of tissue									
2241	2863	3329	3262	2944	6943	3552	3611	3648	2776
94	146	270	190	105	898	275	448	537	151
66	63	138	96	4	1505	308	184	311	66
3032	3572	4979	4562	4463	10121	4708	4372	6529	2089
1360	1258	2567	2245	1389	6316	1531	1616	3082	1865
1288	1381	2453	1858	1736	3577	1521	1725	2086	1297
1344	1333	2310	1985	1840	4727	1893	1892	2914	1512
1413	1980	2065	2768	2673	5076	3367	2861	2790	1847
155	119	637	398	400	1194	10214	560	706	457
857	826	2264	1264	1470	4338	14049	2850	2636	928
106	120	205	224	571	405	380	222	230	143
266	608	803	1049	975	1795	1183	134	800	748
134	181	470	404	432	2968	27576	537	479	78
278	66	630	687	481	1245	5552	899	361	270
745	795	1618	1172	1040	2108	3295	1314	1412	998
139	-	443	299	212	2079	139	933	1230	279
114	362	1296	980	951	9907	17305	1407	1473	370
338	186	557	600	521	152976	6990	837	894	480
216	318	763	672	699	2758	2184	814	1177	644
304	84	382	257	329	11636	567	243	1256	376
428	863	837	1366	2458	4897	2119	1211	1528	910
149	303	267	392	496	441	9211	324	2367	360
-	-	-	371	280	12238	3537	401	-	-
121	573	777	-	-	-	-	-	1265	502

Table 2 (Continued)

11/6/51	11/7/51	11/7/51	11/13/51	11/14/51	11/14/51	11/20/51	11/21/51	11/21/51	11/27/51
#48	#49	#50	#51	#52	#53	#54	#55	#56	#57
Counts per minute per gram of tissue									
2374	4810	3120	2900	3306	2756	2735	2335	2790	3190
100	380	170	200	251	160	133	193	204	118
87	250	80	130	135	105	55	54	58	89
2923	7750	5500	-	6543	1677	3201	2779	3686	4699
1308	3140	2620	1495	2260	1681	1238	1279	1405	1993
1101	2560	1210	1130	2119	1410	1557	1088	1256	1558
1122	2820	1930	1430	1822	1567	1688	1561	1844	2041
1348	2970	2420	1610	2415	2008	1775	1575	1911	2062
256	650	440	440	519	348	230	199	351	213
858	2350	1700	1750	1635	1246	984	658	1202	1083
128	260	190	180	190	127	131	102	157	118
597	1000	280	670	704	585	511	399	413	348
277	610	260	470	415	412	269	327	321	129
138	630	-	-	-	579	219	394	903	613
1281	1470	1190	1180	414	653	591	539	612	961
69	610	-	-	-	568	-	-	187	39
-	980	1170	690	1220	738	214	633	1360	-
313	960	500	390	771	435	300	252	396	269
473	960	600	560	762	427	285	294	403	311
212	490	350	310	395	234	330	243	395	180
620	980	930	1600	849	492	1512	-	1199	887
445	270	130	450	163	248	32	94	448	153
-	1600	310	-	365	218	236	180	625	-
486	-	-	210	-	-	-	-	-	319

Table 2. (Continued)

11/27/51	11/28/51	12/4/51	12/5/51	12/6/51	12/11/51	12/11/51	12/12/51	12/18/51	12/19/51
#58	#59	#60	#61	#62	#63	#64	#65	#66	#67
Counts per minute per gram of tissue									
2123	2379	2474	2455	2197	2410	2834	2560	2849	1753
69	-	33	88	65	139	190	86	144	73
76	82	41	36	81	75	90	49	82	54
3258	3832	3961	3599	4210	4584	5497	3117	3625	3428
1450	1653	1786	1504	1835	1550	2199	1617	1520	1505
1353	1302	1453	1408	1211	1637	1797	1387	1560	1100
1256	1211	1730	1630	1182	-	2098	1475	1728	1283
1562	1588	1544	1659	1836	2194	2367	-	2066	1543
132	195	156	154	169	232	172	57	281	65
843	955	939	841	979	1155	931	862	1006	760
101	101	98	77	109	112	118	65	116	81
266	275	161	189	440	636	303	504	635	249
58	219	119	84	194	329	352	313	417	81
406	386	45	160	241	214	532	79	359	192
1180	556	417	390	943	1097	917	538	758	585
144	211	54	116	24	260	828	55	271	161
141	485	-	-	495	436	1333	707	164	-
187	425	94	130	332	411	456	225	326	159
154	248	172	209	281	412	165	242	423	107
95	154	24	137	163	63	159	83	172	117
460	469	521	248	1617	1552	1348	2721	1332	1258
146	44	-	59	239	260	147	100	439	25
-	-	140	143	-	-	-	133	244	-
169	-	-	-	219	574	1397	-	-	207

Table 2. (Continued)

12/19/51	12/27/51	12/27/51	12/28/51	1/3/52	1/3/52	1/4/52	1/9/52	1/9/52	1/9/52
#68	#69	#70	#71	#72	#73	#74	#75	#76	#77
Counts per minute per gram of tissue									
2232	1887	2141	1729	1879	931	2807	2170	2419	2125
-	64	20	39	70	60	190	54	137	150
28	29	25	38	33	28	37	82	147	150
3185	2697	3786	2518	2645	2704	4747	3312	2058	4909
1290	1309	2019	1506	1214	1056	1900	1253	1390	1910
1394	1372	1505	1318	1062	1014	1699	1123	1467	1423
1439	1269	1669	1349	1214	1254	1866	1378	1431	1812
1679	1814	1680	1219	1410	1165	2204	1749	1869	1672
143	85	134	79	85	114	118	174	198	186
538	558	992	496	649	547	786	779	791	826
73	46	69	49	103	72	89	104	140	119
333	369	233	86	491	97	178	281	265	495
211	202	188	99	267	113	303	308	131	113
18	165	105	145	209	85	37	251	162	352
491	274	533	288	490	246	658	653	2081	958
86	10	21	27	-	215	357	16	294	20
166	219	-	318	791	144	1081	190	461	-
220	231	167	104	212	132	147	265	404	194
240	215	145	190	177	78	-	195	851	209
103	126	109	47	186	80	106	13	1184	90
412	5019	829	134	2507	172	47	1166	24	566
122	130	95	48	184	48	163	-	242	607
114	125	-	51	94	42	164	124	-	-
-	-	22	-	-	-	-	-	248	646

Table 2. (Continued)

1/15/52	1/16/52	1/16/52	1/22/52	1/22/52	1/23/52	1/29/52	1/31/52	2/1/52	2/5/52
#78	#79	#80	#81	#82	#83	#84	#85	#86	#87
Counts per minute per gram of tissue									
2056	1890	2310	1950	1308	2152	1428	1879	1843	1927
49	71	31	87	88	94	111	119	107	37
29	39	-	42	34	31	23	54	10	32
3054	2971	3046	2470	2649	3055	3280	2984	2724	2964
1344	1345	1384	985	1199	1301	1152	1235	1129	1271
1393	1448	1176	1038	1096	1496	1577	1057	1080	1239
1284	1647	1580	1215	1210	1811	1764	1287	1281	1431
1410	-	1692	1434	1511	1840	1510	1431	1532	1659
139	61	39	101	85	117	244	158	159	133
642	533	427	458	640	700	719	1208	594	777
87	61	58	74	64	109	70	63	88	59
294	117	33	153	176	343	366	298	254	200
204	68	101	46	112	151	254	71	148	129
7	0	193	85	30	264	17	250	89	92
789	480	319	663	545	399	705	442	1056	423
58	143	44	336	-	131	266	-	121	730
52	-	137	274	-	306	605	326	-	223
100	107	183	59	97	188	80	246	259	273
86	111	135	88	210	91	120	86	284	154
44	85	38	12	41	44	96	-	129	31
1031	278	263	196	170	2466	732	2310	1474	2522
-	239	53	50	8	-	592	37	244	81
-	102	54	-	83	164	106	34	-	106
31	-	-	-	-	-	-	-	143	-

Table 2. (Continued)

2/7/52	2/8/52	2/11/52	2/14/52	2/14/52	2/19/52	2/20/52	2/21/52	2/26/52	2/26/52
#88	#89	#90	#91	#92	#93	#94	#95	#96	#97
Counts per minute per gram of tissue									
2144	1892	2138	1846	1931	2098	1977	1802	1434	2183
68	34	61	31	64	55	69	62	147	65
14	39	12	33	15	26	38	23	60	64
3436	2841	3130	2838	2975	2919	2643	2831	3628	2900
1558	1251	1367	1232	1292	1350	980	1262	1522	1357
886	1200	1338	1070	1317	1019	1065	1380	1174	1146
1312	1180	1567	1366	1294	1539	-	1284	1499	1516
1670	1589	1744	1277	1770	1475	1376	1487	1803	1456
124	99	110	106	84	49	-	148	426	148
538	560	525	503	528	512	557	538	1318	973
69	63	90	54	55	39	42	65	137	118
100	100	314	412	70	126	114	538	5279	629
179	60	151	199	123	96	183	531	1811	378
-	26	-	31	382	176	-	210	376	218
-	755	548	255	288	849	179	847	1281	600
-	575	101	51	64	-	-	821	209	-
88	186	333	154	-	44	347	475	129	-
210	-	135	45	230	8	140	111	723	481
159	41	121	147	133	-	107	142	481	115
44	175	95	115	10	14	145	22	245	236
1921	595	4511	3002	176	1641	2134	3667	12797	3075
56	-	91	95	379	330	38	473	530	205
-	-	-	63	67	-	60	-	-	118
51	97	33	-	-	No sample	-	260	510	-

Table 2. (Continued)

2/26/52	3/4/52	3/4/52	3/5/52	3/11/52	3/12/52	3/14/52	3/18/52	3/21/52	3/21/52
#98	#99	#100	#101	#102	#103	#104	#105	#106	#107
Counts per minute per gram of tissue									
2453	2084	1981	2868	2645	2495	1903	1933	2730	2530
115	58	102	172	187	287	223	226	222	196
57	46	57	109	61	71	145	114	70	100
2957	3643	3099	3720	4353	4275	2521	3707	3729	3060
1529	1455	1400	1690	1939	1765	1218	1436	1668	1595
1152	1332	1237	1544	1290	1847	1437	1394	1603	1258
1602	1472	1527	1709	2042	1711	1620	920	1675	1040
1924	1636	1735	2106	2162	2265	1618	1517	2202	1754
298	46	146	344	151	183	203	453	187	447
880	493	697	1054	728	939	588	894	740	1193
236	61	68	155	56	79	122	169	126	211
2345	37	211	1179	380	229	511	946	260	805
1635	83	163	446	222	116	342	525	-	574
190	-	185	223	60	940	-	667	280	772
899	642	494	1040	518	650	3718	1053	633	1788
41	33	1327	330	262	-	408	62	69	128
92	68	1000	575	-	446	539	75	76	390
368	243	321	605	206	162	360	367	180	711
297	34	155	240	342	218	426	429	270	626
225	22	111	129	366	-	96	220	40	353
9835	56	688	25388	1664	1691	439	1507	1077	1351
-	270	-	373	30	-	-	350	96	-
125	-	45	200	8	114	-	260	88	-
-	241	-	-	-	-	442	-	-	529

Table 2. (Continued)

3/26/52	3/27/52	3/27/52	3/31/52	4/1/52	4/1/52	4/7/52	4/7/52	4/7/52	4/14/52
#108	#109	#110	#111	#112	#113	#114	#115	#116	#117
Counts per minute per gram of tissue									
2565	2092	2504	450	2067	2239	2420	1978	2320	2537
126	76	120	35	75	130	161	68	23	221
75	17	39	28	30	74	90	11	39	113
3873	2832	3457	2588	3503	3164	2641	2808	4128	3658
1755	1448	1958	1395	1385	1334	1742	1587	1737	1495
1478	1226	1492	904	1420	1576	1169	1420	1631	1480
1607	1234	1685	1220	1472	1584	1409	1557	1564	1667
1731	1487	2149	1196	1757	1810	1500	1558	2021	1897
176	115	173	66	24	189	317	58	150	401
1043	728	436	649	562	839	943	650	1059	1165
139	38	67	80	84	86	130	91	89	131
364	262	432	253	105	840	609	130	376	758
346	163	104	92	153	338	354	85	204	385
295	-	-	192	82	234	399	461	-	-
972	585	746	1436	244	547	1499	900	1076	1026
203	-	-	33	-	56	295	209	721	-
293	155	-	202	287	32	416	221	-	816
112	306	75	163	19	266	344	117	174	324
291	261	198	306	-	216	-	-	-	-
-	16	130	37	92	211	140	74	92	67
577	2394	2717	5930	252	1262	2066	215	940	6533
-	-	-	-	131	-	-	-	-	-
-	72	65	-	26	257	-	-	-	446
370	-	-	32	-	-	520	-	24	-

Table 2. (Continued)

4/14/52	4/15/52	4/21/52	4/21/52	4/21/52	4/28/52	4/28/52	4/30/52	5/6/52	5/6/52
#118	#119	#120	#121	#122	#123	#124	#125	#126	#127
Counts per minute per gram of tissue									
2447	2427	1951	2061	2313	4369	1733	4485	3262	2577
202	196	79	54	181	408	121	473	253	120
57	108	38	62	58	351	75	325	279	77
3970	4170	2961	2539	3866	5611	3427	5730	4739	3219
1810	1755	1074	1488	1660	2430	1493	2885	2373	1697
1546	1807	1155	1328	1430	2277	1568	2381	1876	1517
1768	1831	1360	1419	1666	2581	1802	2654	1950	1669
2134	2236	1280	1438	1769	3142	1685	3478	2447	1772
189	346	213	188	226	834	306	1280	529	256
1079	1251	550	887	1197	2371	1115	2120	1875	1010
94	118	101	79	165	318	102	305	276	119
390	552	417	612	514	1232	708	1590	604	395
87	385	297	146	412	902	413	1098	439	182
-	174	31	41	353	687	328	1267	470	208
985	1282	549	742	669	3318	935	2724	1286	649
-	300	-	153	307	718	-	346	449	-
-	800	352	-	299	899	461	1530	665	147
643	494	92	349	341	1052	306	983	667	302
-	-	-	-	-	-	-	-	-	-
213	150	47	216	160	670	356	536	355	72
3588	2735	1603	8401	1008	2708	1197	5172	779	671
-	-	-	-	-	-	-	-	-	-
57	-	-	318	382	-	487	2700	-	308
-	-	284	-	-	1547	-	-	805	-

Table 2. (Continued)

5/7/52	5/13/52	5/13/52	5/13/52	5/19/52	5/19/52	5/19/52	5/26/52	5/26/52	5/26/52
#128	#129	#130	#131	#132	#133	#134	#135	#136	#137
Counts per minute per gram of tissue									
3196	3106	2234	5010	2748	3122	2909	2680	2072	3345
315	349	358	379	156	246	256	157	83	305
192	260	176	220	130	192	119	107	103	204
3740	4841	4470	8054	3595	3488	3586	3872	3738	3350
1898	2035	2278	3987	2140	1666	2001	2468	1897	2185
1611	1507	1900	2326	811	2137	1735	1923	1346	1586
1590	1989	1796	3275	1522	1702	1888	2034	1494	1988
2538	2671	2603	3630	1771	2420	1632	2082	1522	2339
579	761	831	631	471	554	601	439	316	642
1325	2195	1687	1769	1573	1315	1821	1755	949	1353
207	301	234	245	207	231	151	189	143	212
715	1029	1389	705	883	984	705	686	250	712
607	651	847	544	634	715	469	404	279	349
341	729	627	392	157	542	585	405	755	471
1116	1593	1012	1138	1121	1431	1094	1449	1066	1215
135	471	208	-	290	114	150	-	127	205
255	1235	687	-	956	187	280	-	156	956
625	866	902	665	459	615	486	468	268	709
-	1385	1222	786	883	866	608	547	383	1108
240	349	409	242	361	356	255	260	269	238
1552	1595	2303	1284	1083	1379	865	583	-	908
Stomach contents		-	-	-	-	-	258	-	579
719	-	1276	-	1375	901	416	-	-	-
-	1293	-	826	-	-	-	576	487	865

Table 2. (Continued)

6/3/52	6/3/52	6/3/52	6/10/52	6/10/52	6/10/52	6/17/52	6/17/52	6/17/52	6/24/52
#138	.#139	#140	#141	#142	#143	#144	#145	#146	#147
Counts per minute per gram of tissue									
4582	3348	1612	5910	3728	2971	3030	4354	3313	10665
369	173	140	399	229	189	136	418	249	272
397	89	89	314	104	126	112	298	126	444
9257	4158	2129	10299	3560	3840	3679	6080	3926	19617
4158	2230	1099	5217	2020	1920	1690	3250	2121	8071
3231	1662	671	3300	2012	1302	1508	2484	1728	5397
3099	2207	1147	4610	1496	1832	1909	2643	2028	5533
3273	1885	1153	4512	2392	2312	2259	3120	2262	6771
600	244	266	622	459	474	300	705	379	687
2654	1443	1204	3244	1593	1711	1526	2356	1549	4692
390	149	201	412	170	194	157	161	179	568
728	401	460	449	616	463	542	110	512	591
471	249	317	430	467	382	367	846	223	674
312	296	339	862	570	808	367	673	331	1422
2425	590	1375	2104	836	999	547	3454	1237	2364
625	61	84	417	39	189	124	1199	49	1146
693	241	213	539	-	408	293	703	465	102
869	303	282	815	560	716	332	887	332	972
1324	627	718	297	627	606	470	1787	642	1597
439	138	181	495	83	208	209	419	200	674
-	841	1024	787	-	966	735	1003	373	521
253	798	1143	-	-	-	291	374	428	623
-	476	-	-	563	736	658	-	-	-
1179	-	477	950	-	-	-	1310	415	941

Table 2. (Continued)

6/25/52	6/25/52	7/1/52	7/1/52	7/1/52	7/8/52	7/8/52	7/8/52	7/15/52	7/15/52
#148	#149	#150	#151	#152	#153	#154	#155	#156	#157
Counts per minute per gram of tissue									
3594	3186	8416	3125	3108	4109	6778	16802	4170	4427
28	148	536	221	242	392	357	542	355	305
70	96	496	137	116	158	287	1027	196	147
3901	3988	14421	6052	5752	4756	12727	30160	4411	3729
1853	2454	5142	2946	3209	2346	6002	13343	1998	1349
1799	1667	5146	2186	2150	2142	4751	8576	2154	2354
1988	2353	5319	803	2319	2317	4744	11103	2564	2573
2527	1657	6457	2576	2868	3275	4830	13491	2882	3155
356	275	-	402	425	428	491	1830	557	497
1787	1702	4149	2017	2160	2004	3590	10843	1717	1946
258	230	492	220	230	229	360	1153	312	192
664	472	1003	711	533	638	694	1961	1210	791
496	351	671	671	516	370	495	1792	709	325
1658	1086	1098	428	511	357	408	2318	1371	420
733	1053	4504	1653	1252	1056	3233	5122	2236	1239
285	558	801	780	677	397	456	805	230	282
960	261	1169	668	1111	-	1103	2390	980	685
356	384	1175	625	688	316	576	1620	644	587
625	358	2161	623	966	560	1381	2875	1543	586
240	329	672	317	427	268	333	1394	543	373
1093	866	942	1825	824	943	554	2525	1956	1864
							Fat 132		
709	1054	604	1414	389	913	247	832	1501	1062
578	-	-	-	-	398	-	-	811	635
-	306	1962	689	810	-	639	2462	-	-

Table 2. (Continued)

7/15/52	7/22/52	7/22/52	7/22/52	7/29/52	7/29/52	7/29/52	8/5/52	8/5/52	8/5/52
#158	#159	#160	#161	#162	#163	#164	#165	#166	#167
Counts per minute per gram of tissue									
4227	4259	3648	5417	4339	3926	5002	6422	5153	4217
328	270	268	380	247	295	335	193	263	224
275	153	148	237	134	162	250	289	171	184
6957	4995	4015	-	4063	5985	5848	9143	6193	3788
3170	2418	2005	1697	2021	2965	1443	4742	3100	1996
2139	2562	1999	2663	2084	2449	2773	3600	2449	1926
2840	2916	2396	3266	2159	3241	2934	4023	3231	2049
3080	3007	2620	3943	2641	3047	3910	5095	3118	2878
387	553	570	759	495	703	652	390	554	574
1604	2045	1750	2473	1595	2815	2253	3111	2453	2061
199	325	208	297	240	288	330	289	261	226
469	968	1022	1305	727	993	901	735	659	616
490	754	666	681	617	804	595	316	492	480
918	413	436	640	508	937	604	366	823	579
2371	1475	1347	1996	1350	1931	2830	2424	1651	1185
316	190	-	441	162	160	259	303	449	265
299	1553	385	982	830	1225	1815	657	1577	-
442	887	507	875	416	810	787	494	293	420
1269	1069	1300	1376	671	1269	1103	1380	-	559
300	379	301	253	317	415	567	371	250	448
672	1120	1356	1377	-	1397	889	1170	896	765
464	1203	2432	1582	638	594	377	1110	1196	817
-	755	760	-	-	1362	-	479	-	1698
477	-	-	862	849	-	1038	-	262	-

Table 2. (Continued)

8/12/52	8/12/52	6/12/52	8/18/52	8/18/52	8/18/52	8/27/52	8/27/52	8/27/52	9/4/52
#168	#169	#170	#171	#172	#173	#174	#175	#176	#177
Counts per minute per gram of tissue									
2848	4293	3526	4682	4423	4232	3982	8291	9796	4000
112	218	272	103	163	315	266	478	622	195
63	207	79	128	140	152	86	284	460	128
4556	4558	3463	4935	4742	4474	4068	11265	21765	3674
1705	2474	1883	2622	2440	2363	2144	5006	8131	1740
2166	2376	2205	2597	2571	2361	2111	5144	5876	1812
2300	2097	2427	2850	2528	2983	2372	5187	7914	2143
2408	3080	2568	3181	3250	2705	2620	7342	8974	2232
239	422	308	469	526	625	416	574	1059	265
1445	1681	1630	2143	2045	2200	1718	3713	6626	1456
162	196	156	249	230	225	152	299	787	165
402	408	496	476	407	622	550	766	855	474
262	369	336	325	241	450	439	624	782	453
244	230	522	372	310	390	447	-	2293	560
1094	976	659	1152	2037	854	2861	1793	4868	695
554	82	614	408	249	286	430	1034	738	209
850	719	61	588	-	188	719	1612	2146	36
113	462	444	518	510	761	389	725	2799	434
394	440	594	1009	778	898	629	976	1103	354
154	356	346	410	336	541	301	532	944	141
836	1368	1382	587	641	982	904	1981	1370	5626
956	343	926	619	-	649	869	561	885	5336
-	852	546	846	-	987	-	634	2128	367
368	-	-	-	553	-	460	-	-	-

Table 2. (Continued)

9/4/52	9/5/52	9/9/52	9/12/52	9/12/52	9/18/52	9/19/52	9/19/52	9/23/52	9/24/52
#178	#179	#180	#181	#182	#183	#184	#185	#186	#187
Counts per minute per gram of tissue									
5166	16272	5672	4469	5892	5339	4036	3529	6164	3599
233	674	235	224	194	216	-	63	159	93
147	831	147	132	135	94	91	76	106	67
6331	23394	8434	5573	7405	5872	4688	3440	9422	3918
2899	10068	4157	2877	3118	2354	2062	2164	4614	1933
2608	9667	3943	2753	3034	2729	2125	1960	3912	1895
3149	9679	4428	3032	3478	2731	2366	2503	4750	2464
3705	12133	4238	3154	4532	4045	2936	2518	4835	2504
365	1408	364	250	348	319	209	323	374	228
1820	6655	2451	1717	2354	2111	1539	1338	2708	1534
186	688	257	70	177	168	174	130	112	126
388	1453	526	541	413	518	360	402	472	340
406	886	321	410	474	309	213	127	386	173
309	1118	1185	844	298	551	218	634	610	290
1633	6667	1360	1058	858	1007	808	817	2063	939
963	292	-	-	-	946	152	-	-	966
583	1617	1759	2525	-	312	-	-	490	271
889	1772	373	168	458	235	-	-	779	227
316	3276	576	736	428	1178	779	-	754	84
254	1142	306	344	380	905	131	50	238	286
7842	5116	17467	1519	7164	3827	2117	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2. (Continued)

9/24/52	10/9/52	10/10/52	10/13/52	10/13/52	10/14/52	10/23/52	10/23/52	10/24/52	10/27/52
#188	#189-3	#190-3	#191	#192	#193-3	#194-3	#195-3	#196-3	#197
Counts per minute per gram of tissue									
5562	3145	3162	4331	4612	8068	11371	3962	4931	3304
426	69	91	126	68	292	370	107	192	132
421	30	67	44	94	345	446	46	94	61
6293	3288	3544	5669	6181	10589	16890	3993	6421	3961
3301	1817	1776	2790	2703	5036	6780	2432	3014	1768
2815	1733	2019	2498	3249	4549	6651	2399	3211	1911
3172	2045	2290	3195	3869	5823	8021	2642	3394	2284
4370	2174	2828	2809	3707	4865	7989	2505	3572	2027
1173	213	132	114	364	589	884	149	238	245
2727	1636	1437	1565	2533	2787	3735	1240	1753	1210
380	83	116	144	161	381	461	110	121	123
1468	270	368	365	696	1053	874	443	338	517
1284	206	142	156	323	725	518	121	163	364
933	134	-	328	212	542	724	247	767	-
4360	811	436	1125	1374	4771	3677	677	890	941
1045	-	-	-	-	553	464	-	-	-
1635	89	-	1290	606	1209	1123	-	1404	991
1148	439	308	236	481	866	961	-	952	260
1963	484	672	433	764	2081	2658	324	911	543
1937	159	231	38	138	342	827	174	208	179
1107	1858	545	1090	1373	9029	895	1952	703	5592
718	615	-	827	-	1680	287	2872	-	3181
-	237	184	271	463	-	-	237	322	260
928	-	-	-	-	1087	-	-	-	-

Table 2. (Continued)

10/28/52	10/28/52	11/5/52	11/5/52	11/5/52	11/11/52	11/12/52	11/12/52	11/18/52	11/18/52
#198-3	#199-3	#200	#201	#202	#203	#204	#205	#206	#207
Counts per minute per gram of tissue									
8768	4081	2403	3432	9478	3832	2986	3129	4710	8804
624	15	46	37	560	76	38	72	120	417
578	53	28	40	622	62	34	46	62	383
14737	6993	3575	3814	16020	6127	3820	3492	5954	13249
6369	2834	1900	2042	6567	2510	1903	1909	3166	6516
5960	2660	1548	2000	5674	2709	1826	1781	3085	4876
6964	2870	1802	2344	6669	2942	2088	2126	3542	5724
6564	3297	1586	2070	5228	2653	1687	1948	3398	4771
1065	127	266	126	1452	271	165	248	108	1839
4384	1282	1080	962	4050	1195	1022	1125	1953	3114
1498	108	105	70	517	132	120	97	105	489
840	463	311	312	1806	302	423	523	225	1185
620	190	138	198	932	194	186	182	10	1044
840	564	354	132	880	529	293	154	-	-
8170	1169	1750	718	7422	606	521	739	704	3170
1028	87	206	85	375	412	121	-	-	-
705	2114	311	-	1639	217	225	120	-	-
1236	251	330	308	1419	97	285	361	297	1128
2417	243	351	393	2566	263	401	400	-	-
683	194	205	127	1146	81	89	147	177	738
630	1700	3183	3580	1864	262	1085	1082	1353	1166
-	2047	836	-	-	-	-			
-	116	-	155	-	160	171			
1316	-	309	-						

Table 2. (Continued)

11/18/52	11/24/52	11/24/52	11/25/52	12/2/52	12/2/52	12/2/52	12/9/52	12/10/52	12/10/52
#208	#209	#210	#211	#212	#213	#214	#215	#216	#217
Counts per minute per gram of tissue									
2415	7086	6543	6185	2232	4108	3230	3175	3277	2618
0	325	438	247	74	312	60	38	92	59
75	440	438	252	25	168	23	38	32	8
2974	12290	10385	10612	3788	3670	4157	3264	3915	3018
1570	5856	5647	5025	2025	2437	2520	1711	1832	1503
1500	5257	3849	4115	1810	2090	1380	1565	1668	1070
1296	4908	4401	4710	2286	2710	2325	1838	2220	2088
1702	3627	4487	4095	1980	2800	2313	2627	1865	1437
189	1124	1653	530	190	1037	155	128	149	147
997	3492	3653	2407	1173	2160	1222	1110	1056	742
69	464	422	293	98	284	99	109	83	84
149	1504	2068	603	527	1846	470	185	294	150
132	792	1222	450	188	983	211	61	174	107
-	-	-	-	-	-	-	-	-	-
264	4221	2831	2580	490	2192	537	314	618	500
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
194	1226	973	700	221	1422	310	96	-	-
-	-	-	-	-	-	-	-	-	-
158	787	762	2282	90	524	97	71	53	41
1275	-	-	-	1881	3782	4417	213	1435	2816
858	-	-	-	-	-	-	-	555	1922
140	-	-	-	174	690	136	103	131	131
-	-	-	-	-	-	-	-	-	-

Table 2. (Continued)

12/15/52	12/15/52	12/16/52	12/22/52	12/22/52	12/22/52	12/31/52	12/31/52	12/31/52	1/6/53
#218	#219	#220	#221	#222	#223	#224	#225	#226	#227
Counts per minute per gram of tissue									
2860	6070	2950	2935	2905	2976	3107	3092	3827	3250
116	362	79	35	51	6	118	91	77	64
51	316	41	6	28	37	57	21	39	19
3394	10920	3895	3536	4235	2570	4478	3700	6403	5076
1770	5063	2100	1512	1908	1578	2319	1950	3237	2520
1908	4070	2055	1370	1987	1524	2024	1870	2645	2549
2144	4819	2255	1675	1987	1619	2104	1216	2685	3060
2176	3731	2280	1870	2570	1966	2140	1870	2775	2745
136	625	152	67	181	100	323	126	283	100
959	3385	1234	712	1078	690	1448	1040	1505	924
102	379	94	83	79	61	144	106	122	108
442	729	695	288	2192	222	925	451	1340	180
163	602	304	188	113	255	246	208	557	110
-	-	-	-	-	-	-	-	-	-
732	2453	653	265	1415	322	944	317	1082	691
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
281	785	-	87	169	100	-	-	-	-
-	-	-	-	-	-	-	-	-	-
83	190	115	110	143	86	135	65	138	70
2274	760	8622	1970	662	761	6360	6319	12827	333
-	-	6535	2980	293	-	-	-	14345	325
128	617	256	70	71	86	165	[illegible]	[illegible]	[illegible]
-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2. (Continued)

1/6/53	1/6/53
#228	#229
Counts per minute per gram of tissue	
4870	3195
213	123
97	174
7252	7515
3730	3764
3805	3585
4012	3595
3313	4750
472	525
1882	1616
163	232
1533	433
508	353
-	-
1468	2160
-	-
-	-
-	-
-	-
456	324
10458	547
2378	-
-	-
-	-

Table 3. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of 18 American coots collected from White Oak Lake, Roane County, Tennessee

Bird number	#1	#2	#3	#4	#5	#6	#7	#8	#9
Feathers	-	310	715	230	370	450	605	490	705
Eyes	-	165	260	215	315	280	570	275	515
Bill	-	-	-	-	-	4,390	4,570	5,030	3,200
Brain	-	200	335	280	400	415	925	595	1,100
Skin	-	345	755	-	630	265	1,020	1,000	1,040
Muscle	500	790	675	1,000	1,410	1,040	2,640	2,140	3,750
Heart	215	640	805	965	2,030	950	2,580	1,375	2,220
Thyroid	-	-	3,010	3,060	2,450	1,210	-	-	-
Trachea	-	780	2,280	1,240	1,900	2,300	4,290	2,125	3,430
Lung	300	600	680	690	1,000	710	2,200	1,645	1,720
Pancreas	-	-	2,250	2,300	3,925	2,190	6,000	6,340	4,940
Spleen	-	1,285	1,360	1,460	2,970	1,600	4,390	3,620	3,300
Liver	2,300	1,100	1,250	2,185	2,560	1,050	3,500	2,120	3,570
Gizzard	360	430	680	730	1,180	625	1,760	1,210	1,820
Intestine	280	1,420	1,030	1,400	3,400	1,380	2,435	2,585	2,750
Caeca	-	1,280	2,350	1,500	2,380	-	2,470	2,145	2,000
Kidney	700	1,040	1,220	1,245	2,880	1,080	3,320	2,355	3,030
Adrenals	-	-	-	-	-	-	-	2,800	3,100
Long bone	215	640	1,270	750	1,060	4,560	4,520	2,480	4,360
Ovary	-	-	-	990	2,150	1,140	3,500	-	-
Testes	-	1,000	0	-	-	-	-	-	2,890
Contents of gizzard	1,300	-	1,000	1,420	11,525	850	1,455	445	3,720
Contents of intestine	3,440	2,600	870	1,270	4,060	1,640	-	540	2,350
Contents of caeca	-	54,600	5,670	11,400	15,000	46,600	8,660	11,300	3,400
Contents of rectum	-	22,800	660	1,410	4,890	-	-	835	-

Table 3. (Continued)

#10	#11	#12	#13	#14	#15	#16	#17	#18
450	900	950	550	820	1,040	260	570	500
525	520	470	420	-	510	270	540	285
4,250	7,890	2,700	3,160	3,370	4,050	1,660	3,290	1,890
930	1,010	840	730	760	990	600	840	385
950	920	920	850	700	880	480	1,020	545
2,550	2,570	2,900	2,900	2,670	2,540	1,440	2,230	1,700
2,170	2,330	2,320	2,060	1,850	2,210	1,260	1,840	1,530
960	1,910	1,410	1,940	-	2,600	570	1,050	1,020
5,060	3,850	3,950	4,140	3,450	4,280	1,370	3,460	950
1,530	1,970	2,230	1,840	1,190	1,920	840	1,450	1,290
4,150	5,040	4,550	5,080	4,830	4,470	2,480	5,370	3,990
2,760	3,220	3,360	3,450	3,280	3,240	1,770	3,430	2,560
2,600	2,930	3,510	2,680	2,870	1,480	1,060	3,320	2,210
1,390	1,650	1,260	1,190	1,290	1,340	700	1,410	1,120
3,370	3,200	2,990	2,950	2,610	3,100	1,360	2,630	1,910
2,030	2,450	2,440	2,200	2,060	1,910	1,950	2,200	1,470
2,120	2,940	2,800	2,900	2,520	2,220	1,240	2,640	2,030
2,350	3,190	2,630	2,680	2,190	3,000	1,470	3,990	1,950
6,190	6,710	2,840	4,240	7,550	5,210	1,040	4,110	1,940
2,050	-	2,380	2,270	-	2,330	-	2,190	-
-	4,540	-	-	3,300	-	1,760	-	2,010
5,370	3,300	800	1,240	4,870	5,150	2,020	5,520	2,400
3,940	3,340	2,980	3,070	3,140	9,800	1,370	5,660	2,750
12,000	19,100	22,700	11,600	15,770	6,300	5,100	11,280	-
2,420	2,910	-	-	6,470	2,630	6,400	3,750	-

Table 4. Amounts of radioactivity, in counts per minute per gram, in different tissues of 13 common mallards, collected from White Oak Lake, Roane County, Tennessee

Bird number	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Feathers	30	60	55	2	410	225	920	360	185	120	270	400	140
Eyes	18	12	2	0	16	3	40	2	3	0	10	7	5
Bill	40	40	2	0	80	65	510	85	15	20	130	125	45
Brain	2	10	5	0	35	12	60	25	0	0	20	10	4
Skin	9	50	3	0	10	30	85	13	0	0	8	6	30
Muscle	5	40	5	2	70	30	145	45	3	0	17	30	8
Heart	12	30	10	2	65	20	135	35	4	3	15	30	4
Thyroid	-	1,090	-	-	-	-	-	0	100	0	0	110	-
Trachea	0	55	40	0	210	145	640	210	30	4	310	200	25
Lung	4	50	35	5	55	14	160	30	0	1	0	25	9
Pancreas	20	75	2	0	115	40	380	80	2	10	30	65	0
Spleen	30	80	20	0	0	25	245	80	25	35	0	140	0
Liver	9	40	6	5	60	20	130	45	1	6	9	40	18
Gizzard	5	20	0	2	45	10	85	20	0	7	11	16	0
Intestine	26	60	-	0	80	20	235	18	20	17	16	40	4
Caeca	80	210	35	0	100	14	200	19	45	10	25	70	0
Kidney	14	45	0	0	60	25	280	50	4	3	15	40	18
Adrenals	-	-	9	0	310	205	235	240	60	0	0	0	0
Long bone	20	85	0	8	40	65	430	125	12	11	150	200	30
Ovary	-	-	0	0	-	-	145	-	10	-	-	110	-
Testes	35	185	-	-	85	40	-	100	-	60	40	-	0
Contents of gizzard	80	80	140	35	70	160	2,150	-	40	75	35	2	-
Contents of intestine	50	75	45	0	65	70	1,355	40	30	270	85	30	40
Contents of caeca	465	215	1,200	75	745	380	2,210	80	340	12	3	110	0
Contents of rectum	60	90	-	0	90	0	980	30	9	110	100	40	20

Table 5. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of 8 black ducks collected from White Oak Lake, Roane County, Tennessee

Bird number	#1	#2	#3	#4	#5	#6	#7	#8
Feathers	-	400	840	320	380	670	615	420
Eyes	-	11	30	15	17	0	0	0
Bill	-	75	690	170	300	85	70	35
Brain	-	2	20	40	55	2	0	0
Skin	-	0	40	15	50	8	11	6
Muscle	5	15	45	65	70	9	5	9
Heart	-	20	60	60	60	25	11	10
Thyroid	-	-	0	0	0	0	0	155
Trachea	-	85	380	160	325	75	65	70
Lung	-	60	50	45	50	10	0	9
Pancreas	-	20	190	170	165	45	11	25
Spleen	-	0	130	100	80	30	1	9
Liver	-	7	65	100	65	25	13	8
Gizzard	-	12	55	50	50	16	25	18
Intestine	-	30	120	75	90	55	40	35
Caeca	-	65	110	35	380	120	50	0
Kidney	-	20	130	140	130	25	25	25
Adrenals	-	0	170	8	290	0	65	0
Long bone	40	35	240	210	270	35	50	55
Ovary	-	35	-	-	-	-	90	100
Testes	-	-	80	210	145	50	-	-
Contents of gizzard	-	400	100	60	155	1,180	460	330
Contents of intestine	-	160	670	85	600	1,410	1,250	2,160
Contents of caeca	-	2,070	260	110	770	635	90	145
Contents of rectum	-	1,285	195	30	835	1,500	90	1,950

Table 6. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of 8 wood ducks collected from White Oak Lake, Roane County, Tennessee

Bird number	#1	#2	#3	#4	#5	#6	#7	#8
Feathers	-	245	-	-	-	-	-	-
Eyes	-	3	-	-	-	-	-	-
Bill	-	25	-	-	-	-	-	-
Brain	-	0	-	-	-	-	-	-
Skin	-	5	-	-	-	-	-	-
Muscle	1,360	2	35	25	25	55	25	135
Heart	1,480	0	-	-	-	-	-	-
Thyroid	1,860	90	-	-	-	-	-	-
Trachea	-	30	-	-	-	-	-	-
Lung	1,280	35	-	-	-	-	-	-
Pancreas	2,850	0	-	-	-	-	-	-
Spleen	2,400	12	-	-	-	-	-	-
Liver	1,210	2	90	65	35	240	105	180
Gizzard	880	3	-	-	-	-	-	-
Intestine	1,770	-	-	-	-	-	-	-
Caeca	1,190	-	-	-	-	-	-	-
Kidneys	2,190	0	80	70	50	190	80	215
Adrenals	-	-	-	-	-	-	-	-
Long bone	4,500	0	1,700	35	60	85	3,175	1,885
Ovary	-	0	-	-	-	55	25	230
Testes	-	-	35	50	40	-	-	-
Contents of gizzard	-	20	-	-	-	-	-	-
Contents of intestine	2,420	0	-	-	-	-	-	-
Contents of caeca	9,420	70	-	-	-	-	-	-
Contents of rectum	2,810	45	-	-	-	-	-	-

Table 7. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of two gadwalls and one green-winged teal collected from White Oak Lake, Roane County, Tennessee

Bird number	Gadwall #1	Gadwall #2	Green-winged teal #1
Feathers	165	665	160
Eyes	50	335	110
Bill	240	1,645	815
Brain	70	480	160
Skin	-	820	300
Muscle	140	1,170	490
Heart	205	1,300	470
Thyroid	8,950	2,100	1,060
Trachea	225	2,650	950
Lung	150	1,100	330
Pancreas	265	3,450	1,460
Spleen	275	2,300	-
Liver	545	2,346	530
Gizzard	150	1,265	390
Intestine	590	2,800	710
Caeca	440	1,810	510
Kidneys	320	2,080	720
Adrenals	-	-	-
Long bone	270	2,270	1,025
Ovary	160	1,830	740
Testes	-	-	-
Contents of gizzard	5,400	3,640	50
Contents of intestine	775	2,850	350
Contents of caeca	12,500	38,200	1,050
Contents of rectum	2,415	4,120	910

Table 8. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of several species of amphibians and reptiles collected from White Oak Lake, Roane County, Tennessee

	Bullfrogs		Cumberland turtle	Map turtles		Soft-shell turtles		Snapping turtles		
Number	#1	#2	#1	#1	#2	#1	#2	#1	#2	#3
Blood	8	20	10	12	13	40	30	35	50	110
Skin	55	95	35	45	20	45	40	880	600	425
Muscle	1	12	45	55	25	30	60	55	55	30
Long bone	400	730	3,165	6,480	4,060	890	1,820	4,650	5,060	6,180
Lung	7	9	25	35	16	45	70	30	40	13
Pancreas	0	50	75	55	35	95	30	60	70	90
Eyes	5	8	70	300	70	40	100	100	120	150
Stomach	9	30	35	40	30	70	75	50	55	45
Intestine	15	35	50	55	25	100	45	135	160	145
Heart	0	30	25	55	30	85	55	40	60	65
Liver	70	135	40	55	35	125	55	75	125	100
Gall bladder	0	0	-	105	-	40	-	25	-	17
Spleen	7	65	55	55	55	110	35	60	100	50
Kidney	55	90	280	330	185	160	75	270	330	310
Thyroid	30	-	20	-	-	-	-	-	-	-
Brain	40	100	30	95	9	65	20	90	75	215
Ovary	20	65	-	-	160	50	165	-	-	-
Testis	-	-	45	45	-	-	-	55	80	135
Oviduct	20	40	-	-	25	-	40	-	-	-
Toenails	-	-	1,265	2,020	1,430	420	990	2,330	2,450	2,750
Bill	-	-	3,180	6,450	3,870	-	-	85	1,670	8,840
Carapace	-	-	3,040	5,420	2,715	-	3,080	3,770	4,250	7,340
Plastron	-	-	3,570	7,350	3,540	900	2,020	3,480	4,440	6,725
Contents of stomach	265	205	835	-	-	-	360	-	-	-
Contents of intestine	190	460	1,350	-	-	4,450	770	725	520	210
Contents of rectum	220	500	6,640	-	-	-	270	4,100	5,200	2,410

Table 9. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of several birds frequenting White Oak Lake, Roane County, Tennessee

	Green heron			American egret		Kingfisher
Number	#1	#2	#3	#1	#2	#1
Feathers	45	340	400	510	110	100
Eyes	7	55	230	55	55	90
Bill	0	110	3,860	100	180	1,120
Skin	0	230	120	140	150	230
Brain	13	120	310	50	90	130
Esophagus	35	290	460	170	90	260
Muscle	4	330	590	135	180	480
Thyroid	0	1,160	-	730	530	3,280
Lung	0	270	410	170	200	280
Liver	2	420	870	240	150	580
Spleen	0	440	790	340	330	810
Heart	0	350	680	210	830	390
Gall bladder	0	-	450	-	180	620
Pancreas	0	750	1,270	460	530	740
Gizzard	135	360	500	250	450	530
Kidney	20	740	1,370	400	350	420
Intestine	80	410	700	270	380	580
Ovary	-	180	-	220	220	-
Testis	-	-	3,370	-	-	-
Long bone	3	560	2,800	550	100	1,600
Contents of gizzard	8	1,870	-	860	1,120	3,190
Contents of intestine	130	610	1,110	520	600	520
Contents of rectum	55	8,750	3,260	750	10,300	800

Table 10. Amounts of radioactivity, in counts per minute per gram, accumulated in different tissues of several species of mammals collected near White Oak Lake and White Oak Creek, Roane County, Tennessee

	Muskrat							Raccoon		Gray squirrel	Woodchuck
Number	#1	#2	#3	#4	#5	#6	#7	#1	#2	#1	#1
Hair	210	2,530	145	580	290	165	1,950	7,570	1,220	100	18,400
Eyes	85	90	125	120	160	35	100	30	10	0	720
Blood	75	25	160	-	-	-	-	65	40	-	-
Toenails	3,160	770	1,470	1,140	960	1,350	78,400	500	800	20	3,400
Brain	140	25	160	45	10	50	125	0	15	0	1,250
Trachea	850	270	1,070	430	95	-	49,000	60	65	0	1,820
Muscle	240	70	200	70	56	215	55	60	40	15	3,740
Lung	340	40	200	770	95	55	50	620	65	5	3,130
Liver	360	80	460	120	105	45	130	50	110	0	3,000
Spleen	370	165	480	110	190	115	45	30	70	20	2,580
Heart	260	55	340	80	150	90	430	25	55	0	3,070
Pancreas	270	40	450	130	140	10	80	35	75	25	1,960
Stomach	310	45	180	75	110	85	90	35	-	10	3,990
Intestine	320	65	360	120	210	110	55	55	130	635	3,640
Caecum	270	90	210	120	230	195	75	30	-	40	2,530
Testis	-	65	250	70	-	-	-	15	35	-	-
Ovary	370	-	-	-	75	175	500	-	-	-	2,770
Kidney	470	90	430	110	180	165	115	25	75	10	4,570
Adrenals	450	60	470	130	17	110	20	20	90	40	-
Salivary gland	440	100	370	120	130	105	100	55	-	-	3,230
Long bone	13,044	3,320	11,440	2,910	2,830	4,740	246,000	45	110	90	5,500
Contents of stomach	1,020	540	50	810	650	95	130	920	-	45	1,800
Contents of intestine	700	600	210	600	610	145	95	1,020	-	3,640	2,400
Contents of caecum	2,170	1,270	770	1,190	3,650	1,540	-	-	-	635	8,920
Contents of rectum	3,170	3,900	-	1,860	-	3,980	190	900	4,370	890	13,650